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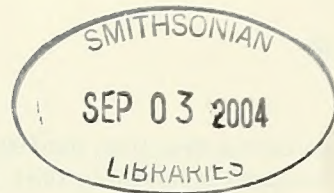
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**Cover illustration:** An Underwing Moth (*Catocala* sp., Noctuidae) plays "hide and seek" on the bark of a Silver Maple tree, central Illinois, USA. Photo by Mike Toliver





# JOURNAL OF THE LEPIDOPTERISTS' SOCIETY

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## THE TAXONOMY, LARVA AND ECOLOGY OF *AGROTIS BUCHHOLZI* (NOCTUIDAE) WITH A NEW SIBLING SPECIES FROM NORTH CAROLINA

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**ABSTRACT.** *Agrotis buchholzi* is one of four Lepidoptera species believed to be endemic to the New Jersey Pine Barrens. It occurs primarily in recently burned or exceptionally xeric or sterile areas where its sole larval foodplant, *Pyxidanthra barbulata* (Diapensiaceae), occurs in openings in the shrub layer. Adults can be quite common locally. There are two broods approximately two months apart with the first starting about late May. Hibernation is as prepupal larvae in the sand. The larva is similar to that of other species of *Agrotis*. Adults are very active and feed but their natural food sources are not known. A sibling species, *Agrotis carolina*, new species, is closely associated with *P. barbulata* in southeastern North Carolina. Its range resembles that of another endemic, *Hemipachnobia subporphyrea*. The combined ranges of these two *Agrotis* are very similar to those of an unnamed *Cyclophora* (Geometridae) and *Spartiniphaga carterae* Schweitzer (Noctuidae) and their habitats commonly overlap in both states. Fire is a crucial factor in forming and maintaining habitat for all of these species. *A. buchholzi* may become imperiled because of a decline of wildfires. *A. carolina*, but not *A. buchholzi*, is thriving in habitats maintained by prescribed burns.

**Additional key words:** Sand plains, bivoltine, larval hibernation, *Agrotis obliqua*, *Agrotis stigmata*, monophagy.

Since its description very little has been published about the habitat and nothing about the life history of *Agrotis buchholzi* (Barnes & Benjamin) (Noctuidae) and its foodplant has not been reported. Forbes (1954) knew this species only from the two types from Lakehurst, New Jersey and indicated (correctly) that their dates suggested two annual generations. Franclemont (1956) reported the collection of the first substantial series, and his collection contained (as of 1974) 34 collected from 31 July to 15 August, 1955 and 19 collected 28 May to 10 June, 1956. Several collections have a few specimens taken by Otto Buchholz, Fredrick Lemmer and Joseph Muller, all vicinity of Lakehurst, but only Franclemont had encountered it in numbers. The late J. W. Cadbury III had a specimen from Browns Mills (now in Schweitzer coll.) which extended the range southwest into adjacent Burlington County.

More recently one of us (TLM) collected a specimen near Atsion, Burlington County, on 25 May 1976, but DFS failed to encounter it at nearby Batsto during

intensive collecting from 1969 to 1977. In 1977 James Madenjian collected 46 specimens on the West Pine Plains east of Chatsworth and a few about nine miles to the west in Lebanon State Forest, both in Burlington County, during field work for his master's thesis at Rutgers University, where a few specimens currently reside. Most of his specimens were discarded. During late May and early August 1980 DFS found the species to be comparably abundant at the West Pine Plains site. Other records in the 1980's (all DFS and/or W. J. Cromartie) were from a burn scar near Atsion, another near Papoose Branch and an unburned site in the East Pine Plains, all in Burlington County, and at the Lakehurst Naval Air Station in Ocean County. In 1994 DFS collected several on the approach zone of Atlantic City International Airport, Egg Harbor Township in northern Atlantic County, New Jersey, increasing the known range to parts of three counties. That small population may originally have been a bit disjunct and is quite isolated now. Another was taken about 3 km to the south by Thomas Hupf in 2000, ap-



parently a stray from the 1994 site as no intervening foodplant is known. In 1994, 1995 and 1996 DFS located enormous populations in the Impact Area at Fort Dix Military Reservation, in Ocean County, with 47 being taken in two blacklight traps the night of 12 August 1994 alone. Lesser numbers were taken on several other nights in June and August. The known distribution thus encompasses parts of three contiguous counties. It could turn up in extreme eastern Camden County a few kilometers west of Atsion.

Although the Pine Barrens region has always been mapped by botanists to include a much larger area (e.g., Stone 1911, Harshberger 1917, McCormick 1970), habitat for *A. buchholzi* and most other specialized Pine Barrens Lepidoptera is very limited south of the Mullica River, becoming more so because of the elimination of large scale fires and development in eastern Atlantic County. Contiguous large tracts of true pine barrens habitats are confined to the region from about Lakehurst to Batsto. *Pyxidanthera barbulata* Michx., the food plant reported below, is scarce in Cumberland County (e.g., Moore 1989) and infrequent, usually in small numbers, in most of Atlantic County, having disappeared from former stations around Pomona since the 1970's probably because of lack of fire (W. J. Cromartie pers. com. to DFS).

#### LIFE HISTORY OF *AGROTIS BUCHHOLZI*

**Phenology.** *Agrotis buchholzi* has two broods with adults present for about two to three weeks each year between 15 May and 15 June; and for a similarly short period between about 17 July and 15 August. Adults are nocturnal and fly almost exclusively before midnight in both broods. They have not been observed at dusk.

**Adult behavior.** Captive adults are extremely active and alert even when disturbed in the daytime. They are also very active at collecting sheets. They apparently do not live more than a week. Adults are difficult to get in perfect condition as they quickly become battered and worn, apparently from moving rapidly through fallen pine needles, cinders, twigs, dead leaves and ashes. The moths are best collected at lights.

Adults do feed, and occasionally the summer brood adults come to sugar bait. Spring brood adults avidly nectar from *Leiophyllum buxifolium* Berg. (Ell.) blossoms in captivity, and would usually have easy access to this and a variety of other flowering low shrubs in the field. However, we have not found any on flowers at night. Summer brood adults would usually not have access to flowers but might be able to locate rotting or damaged berries of Ericaceae. Adults readily accept honey or maple syrup solutions and overripe fruit in confinement.

**Foodplant and larval behavior.** In 1980 DFS obtained eggs from two females, as had Franclemont previously. No suitable foodplant was found although some larvae fed on a species of *Hudsonia* (Cistaceae) but were promptly poisoned by it. In 1988 we found all of over 100 species of plants, including a somewhat wilted piece of *Pyxidanthera* and several grasses, to be unacceptable. By the end of the 1988 field season it was obvious to DFS that *Agrotis buchholzi* could be obtained consistently by placing light traps in large concentrations of *Pyxidanthera barbulata*. Thus it seemed obvious that either this plant or an abundant associate, such as *Leiophyllum buxifolium*, would prove to be the larval foodplant.

On 4 August 1989, five worn females were collected alive from three 15-watt blacklight setups on the Lakehurst Naval Station by DFS and Thomas Breden. All five were fed the next day and placed in sealed plastic boxes with foliage of the above three plants. All females laid some eggs, two of them a substantial number. Most eggs were laid 6 to 9 August. The majority of eggs were placed on the foliage or stems of the *Pyxidanthera* but some were placed on paper or on the *Leiophyllum*. Eggs hatched on about the seventh day after oviposition and the first few larvae were found to feed readily on fresh *Pyxidanthera*, but not at all on *Leiophyllum*, *Hudsonia* or *Xerophyllum* (Liliaceae). Herbaceous dicots were not tried this time because most *A. buchholzi* habitats are composed almost entirely of woody species and lichens, sometimes with grasses or sedges present.

Cuttings of *Pyxidanthera* remained fresh for over two weeks in plastic containers; larvae were left undisturbed except to add new foliage and to make observations. One group of eggs was transferred to potted *Pyxidanthera* before hatching and larvae allowed to feed on this for about a month until the foodplant was severely defoliated by the third instars. Larvae were thereafter all placed in sealed plastic containers and fed fresh cuttings as needed. Cuttings were sometimes stored in a refrigerator for up to two weeks before use. The potted plant was covered with thin muslin, but this was probably an unnecessary precaution as the larvae showed no tendency to climb.

Once feeding commenced, larvae were very sluggish and usually remained hidden in accumulated frass. The frass appeared to be quite sticky and became mixed with sand grains forming piles adhering to the foliage or stems of the foodplant. By the third instar, larvae on foliage actually touching the sand tended to hide in the upper most sand grains while not feeding and some others often moved to the base of the plants or the soil rather than remain among their frass. Later instars became more subterranean and the last two in-



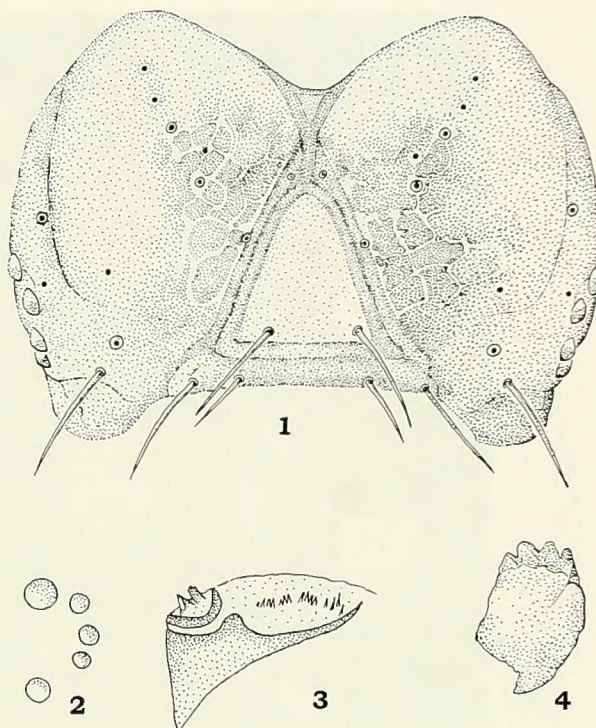
stars emerged from the soil only to feed. Feeding was almost always at night except during cold weather in October when diurnal feeding was observed.

Although cuttings of *Leiophyllum* and several *Eri-caceae* were frequently added with the foodplant when feeding the older larvae, these plants and the grass *Calamovilfa brevipilis* were never eaten. On 13 September 1989 DFS collected a single third instar larva on *Pyxidanthera* near Atsion. It is virtually certain that the larvae feed exclusively on this plant.

Reared *A. buchholzi* larvae reached full size outdoors by early to mid October, but continued to feed for a few more weeks. First brood larvae obviously mature faster since the second brood adults appear within two months of first brood adults. All of 65 larvae (from two females) counted on 15 September reached maturity. However, 10 died in late October or November, probably from a pathogen. By 10 November, all survivors appeared to have completed feeding and most were apparently in an early pre-pupal condition. Most had formed cells in the moist sand, but sometimes appeared briefly at the surface. The containers holding the hibernating larvae were placed in a thick styrofoam box, and buried in peat moss and left outside on a sheltered porch. December of 1989 proved to be the coldest December on record in the region and when seasonable conditions returned at the end of the month the peat was frozen and all but six of the 50 larvae were dead. These six were removed to a refrigerator until 8 March 1990. Three appeared at the surface later that month and formed new pupal cells at the surface. All three pupated in April and eclosed in mid May. They did not feed after November.

According to McCabe (1981) the related *A. stigmosa* Morrison [as *Agrotis volubilis* Harvey] also diapauses as a mature larva by late summer and overwinters in that state. He too had difficulty overwintering the larvae. Crumb (1956) reported a prolonged spring and summer larval diapause in *A. venerabilis* Walker, a common species in grassy places with adults in early autumn.

The apparent monophagy of *A. buchholzi* is unusual, but not unique, for the group of genera (including *Euxoa*) combined as *Agrotis* by Forbes (1954). The undescribed *Mesembragrotis* illustrated by Handfield (1999) is monophagous in New Jersey on flowers and ripening seeds of the grass *Calamovilfa brevipilis*. *Richiaacclivis* (Morrison), which is similar in genitalia, adult and larval appearance, phenology and behavior, is also a specialist on flowers and seeds of a grass, *Panicum virgatum* L. at least in New Jersey (DFS). Our larvae of *Trichosilia manifesta* (Morrison) accepted only oaks but apparently become more polyphagous after hibernation (Crumb, 1956), when oak is unavailable.



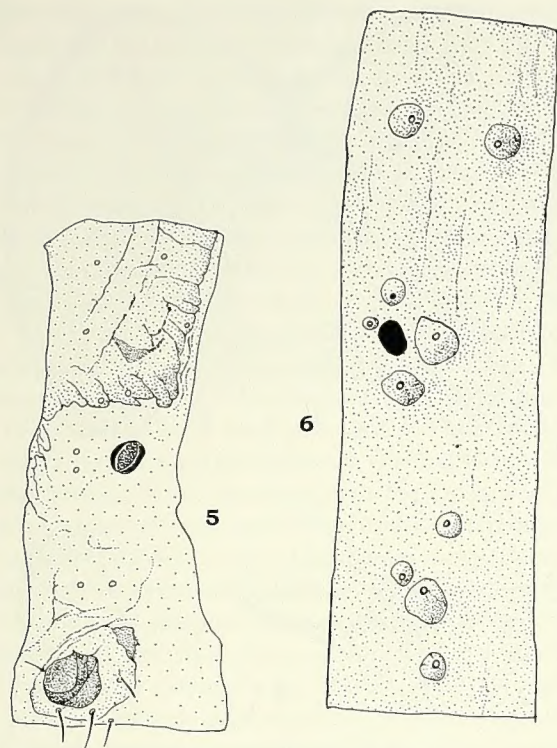
FIGS. 1-4. *Agrotis buchholzi* larval head features. 1, Head, frontal aspect (most head setae worn or broken off). 2, Ocellar arrangement, lateral view. 3, Hypopharyngeal complex. 4, Mandible, oral face. All larvae reared ex ovis on *Pyxidanthera* from Naval Air Station near Lakehurst, New Jersey.

**Larval description of *Agrotis buchholzi*.** First instars were not examined in detail. They had no obvious pattern and moved in the looping fashion typical for first instar Noctuidae. Second and third instars were slightly reddish with little pattern other than ill-defined dorsal and lateral pale lines. Virtually all patterns were lost by the penultimate instar and the older larvae were a rather uniform blackish brown much like the caterpillar of *A. stigmosa* illustrated by McCabe (1981). There appeared to be six instars, but close observation of young larvae was difficult and the number of instars was not established with certainty.

The diapausing prepupal larvae were preserved after they died. This made for less than pristine preserved larvae with considerable erosion and breakage of setae. Consequently, not all setal bases had their setae intact and, therefore, are not represented in the illustrations.

**Last (sixth?) instar larva.** General: The average head width (as viewed from the face) 2.1 mm; average total body length (head to tail, natural resting posture) 25.1 mm; abdominal prolegs present on 3rd through 6th and 10th segments; setae simple; crochets a unioordinal mesoseries; spiracle AS 0.33 mm high on average ( $n = 10$ ). Coloration (living material): Head with a brown pavement pattern towards front of face only. Body brown-black with a conspicuous lateral series of black spots, two on each segment, comprising the spiracle and the L1 pinaculum. Head capsule (Fig. 1): Epicranial suture 0.27 mm long; height of frons 0.97 mm; second adfrontal (Af2) anterior and 1st adfrontal (Af1) posterior to apex of frons; coronal punctures Aa, pa, pb, and 3 ultraposterior (2 visible in frontal aspect) present as illustrated. Hypopharyngeal complex (Fig. 3): spinneret shorter than labial palpus, apex lacking setae; stipular seta (S) at an-





FIGS. 5–6. *Agrotis buchholzi* larval body segments. 5, Prothorax, semidiagrammatic (most body setae worn or broken off). 6, First abdominal segment. All caterpillars reared ex ovis on *Pyxidanthra* from the Naval Air Station near Lakehurst, New Jersey.

terodorsal region of prementum; distal region of hypopharynx bears numerous very fine spines, followed by a single row of 14–15 large spines that extend to the posterior apex of prementum. Mandible (Fig. 4) with inner ridges indistinct, lacking basal tooth. Prothorax (Fig. 5): cervical shield well sclerotized; subdorsal setae (SD1 & SD2) on the shield; prespiracular setae (L1 & L2) and subventral setae lacking pinaculi. First abdominal segments (Fig. 6): subventral setae (SV1 & SV3) approximate; L1 posterior to spiracle; SD2 anterodorsal to spiracle; spiracle 0.31 mm high. Ab2–6 with 3 subventral setae; SD2 setal base anterior to spiracle. Ab7&8 with only 1 seta in subventral group. Tarsal claws are without a basal tooth. The hind coxae are approximately the femur length apart. Crochets a uniordinal mesoseries. Actual crochet counts were not practical because of the state of preservation. Material examined. Ten specimens, Lakehurst Naval Air Station, Ocean County New Jersey, 6 December 1989, from ova of female collected and determined by D. F. Schweitzer.

*Agrotis buchholzi* larvae differ from *A. stigmata* (see McCabe 1981) as follows: head coronal puncture (pb) out of line with setae P2 and P1; the L1 pinaculus, on the first abdominal segment, less than half its width from the pinaculus L2 (this distance is twice L1's width in *A. stigmata*) and the SV3 pinaculus well formed and near to SV1.

Multiple rearings of *A. venerabilis* have shown variability in the size of the L1 pinaculum. If this holds for *A. buchholzi* it could affect the apparent distance between it and the L2 pinaculus. If run through Crumb's keys, *A. buchholzi* appears closest to *A. gladiaria*, but Crumb (1956) did not have the related *A. obliqua* as its larva is unknown.

**Relationships.** *Agrotis buchholzi* fits in a group that includes *A. obliqua* (J. B. Smith) (Fig. 10). These moths are all very similar in appearance and male and female genitalia, although the latter typically has the orbicular dark throughout, unlike the lighter ring seen in *A. buchholzi*. The food plant of *A. obliqua* has not been established, but it occurs in the absence of *Dia-pensiaceae*. The polyphagous *A. volubilis*, *A. stigmata* and *A. venerabilis* are also morphologically close to these three. *Agrotis buchholzi* also has a sibling species, previously treated in collections as a southern disjunct, which we consider distinct.

### *Agrotis carolina* Schweitzer & McCabe, new species

(Figs. 7–9, 14, 16, 18, 19)

**Adults:** Male and female similar (Figs. 7, 8). Vertex of head a reddish brown; frons and tips of palpi light brown; antennae subpectinate; tegulae with a black band; patagia with silvery gray scales, lighter than disk; abdomen untufted; wings violet gray with am line wavy, bowed out considerably below fold, with subtle pinkish cast to basal area in fold; orbicular round, reniform kidney shaped, region between orbicular and reniform and costa darker; median line usually present though sometimes lacking; pm line dentate, evenly ex-curved; terminal line a broken series of black spots; fringe concolorous with ground; wing expanse (spring brood) = 32–38 mm ( $n = 55$ , average = 34 mm), second brood wing expanse = 26–30 mm ( $n = 9$ , average = 29 mm).

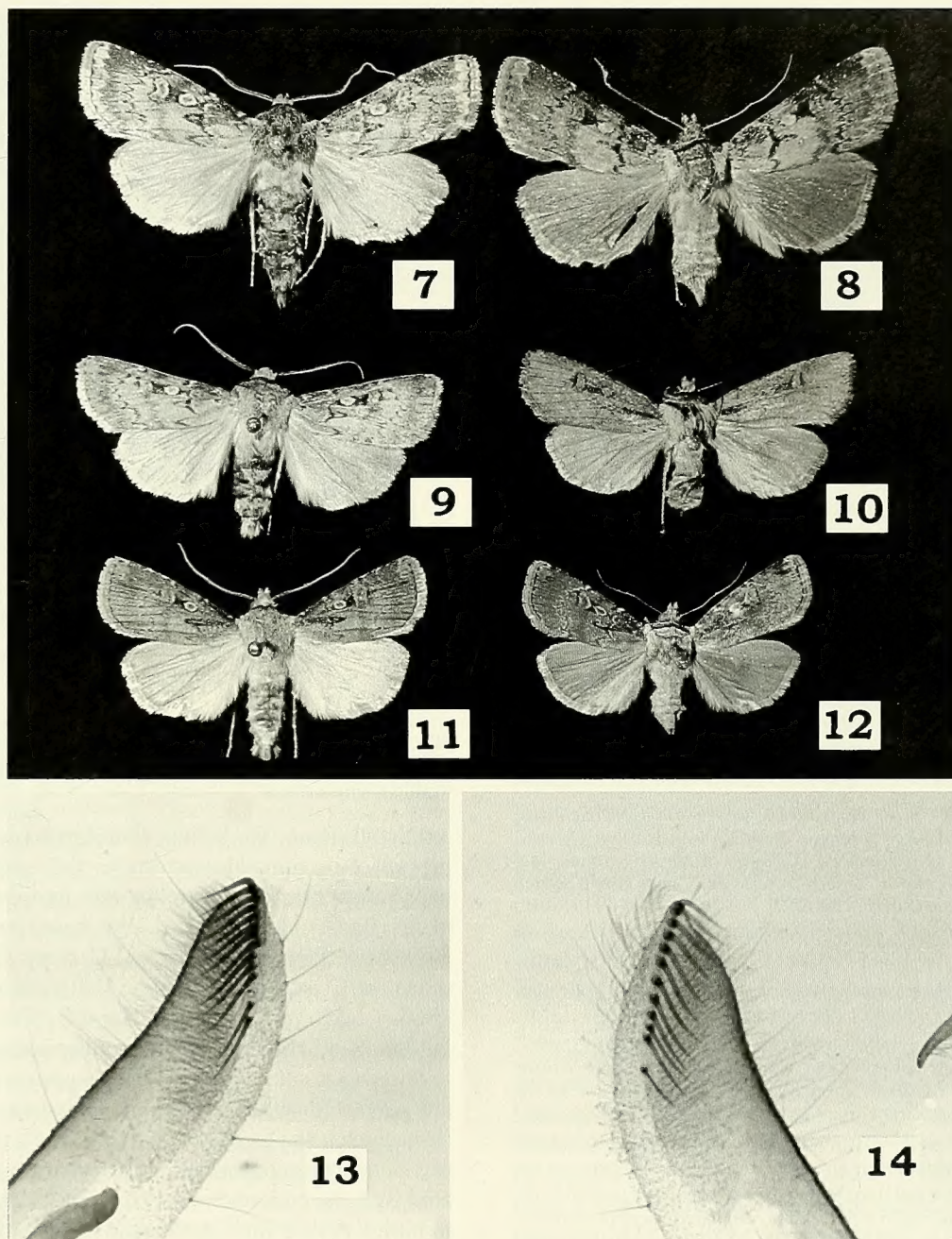
**Male genitalia** (Figs. 14, 16, 18): Valves nearly parallel-sided, bluntly pointed (Fig. 16). Harpe present, length about half width of valve, bluntly rounded and directed slightly towards outside. Cucullar spines loosely spaced, with room enough for additional spine between many bases (Fig. 14). Everted vesica with chitinated basal band (Fig. 18). Remainder of vesica an elongate tube, slightly curved, and swollen towards end.

**Female genitalia** (Fig. 19): Ovipositor lobes short, unmodified. Anterior apophyses extend half way to branch of appendix bursa. Ductus bursa nearly twice length of anterior apophyses. Corpus bursa a long tube with swollen apex. Appendix bursa much longer, narrow, coiled once upon itself, with gradually swollen apex. Ductus seminalis issues from apex of appendix bursa. The lengthy appendix bursa coils inwardly over itself. This is evident when the bursa is inflated in alcohol and was sketched at this stage in the dissection. The appendix bursa had to be accurately "arranged" in the thicker mounting medium.

**Holotype:** Male, North Carolina, Brunswick Co., vic. Supply, Green Swamp Preserve, dry savanna, 12 April 1991, S. Hall & D. Schweitzer.

**Paratypes** (68—all North Carolina, approximately a 3:1 male to female ratio): (6) Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 11 June 1991, 12 April 1991, S. Hall & D. Schweitzer; McCabe slides 2567, 2663, 2664, 2879; (3) Brunswick County, 2 mi. SW Boiling Springs Lakes, 28 June 1994, J. B. Sullivan, R. Broadwell, & B. Smith; (1) Brunswick County, MOTSU, Intersection of firebreaks 32 & 34, 11 April 1994, J. B. Sullivan, R. Broadwell, & B. Smith; (23) Carteret County, Millis Savannah, 34.45.19N–76.59.23W, 29 March 1998, T. McCabe, McCabe slide 3721; (18) Onslow County, Camp Lejeune, 4 April 1995, S. Hall; (3) Pender County, 3.2 mi. N. Maple Hill, Angola Creek Preserve, 13 April 1991, S. Hall & D. Schweitzer, McCabe slide 2568; (8) Pender County, Holly Shelter, Old Rd./BJ Rd., 5 April 1995, S. Hall.





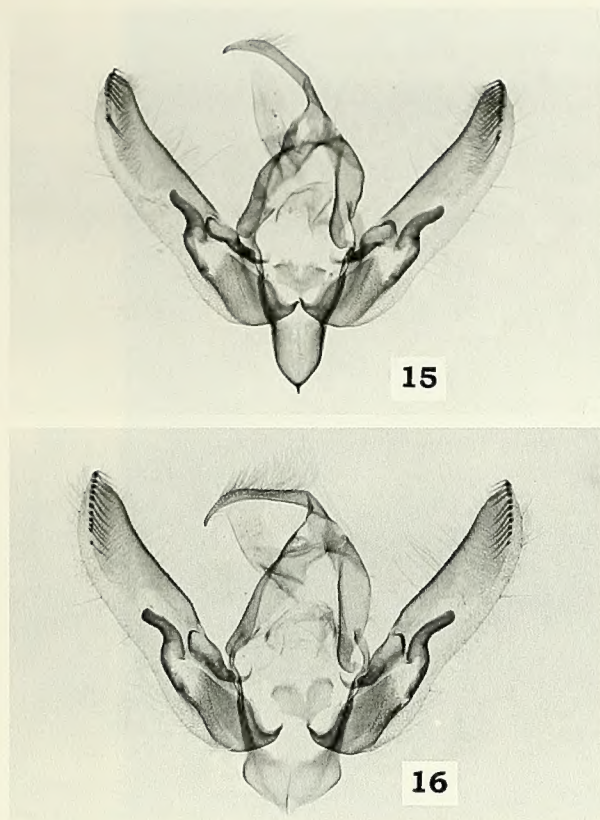
FIGS. 7–14. Adults. **7**, *Agrotis carolina*, first brood male, **Holotype**, North Carolina (Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 12 April 1991, S. Hall & D. Schweitzer). **8**, *Agrotis carolina*, female, North Carolina (Pender County, 3.2 mi. N. Maple Hill, Angola Creek Preserve, 13 April 1991, S. Hall & D. Schweitzer). **9**, *Agrotis carolina*, second brood, North Carolina (Brunswick Co., vic. Supply, Green Swamp Preserve, dry Savannah, 11 June 1991, S. Hall & D. Schweitzer). **10**, *Agrotis obliqua*, female, Labrador (Lower Brook, 55.15.52–60.52.29, 15 July 1993, J. Bopp). **11**, *Agrotis buchholzi*, male, New Jersey (Ocean County, Fort Dix impact area, 12 August 1994, D. Schweitzer). **12**, *Agrotis buchholzi*, female, New Jersey (Ocean County, Lakehurst N.A.S., ex ovis, reared late April, ecl. 2 June 1990, D. Schweitzer). FIGS. 13–14. Cucular spines. **13**, *Agrotis buchholzi* (same data as Fig. 15). **14**, *Agrotis carolina* (same data as Fig. 16).

**Deposition of type material.** Holotype male is deposited in the US National Museum of Natural History, Washington, D.C. Paratypes are in that collection, the New York State Museum, the Schweitzer collection, the Sullivan collection and the McCabe collection.

**Diagnosis.** *Agrotis carolina* resembles a large version of *A.*

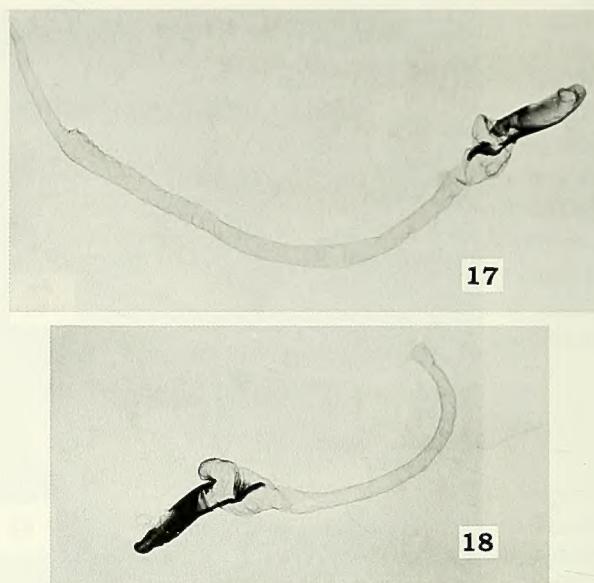
*buchholzi* (34 mm vs. 27 mm for first brood, 29 mm vs. 27 mm for the second brood). Size and distribution will allow easy determination, although almost all adults are paler and much more strikingly marked than *A. buchholzi* or *A. obliqua*. *Agrotis obliqua* (Fig. 10) occurs in boreal habitats and typically has the orbicular dark throughout. The morphological differences between *A. carolina* and





FIGS. 15–16. Male genitalia. **15**, Valves of *Agrotis buchholzi*, McCabe slide 2569, New Jersey (Ocean County, Lakehurst N.A.S., 4 August 1989, D. Schweitzer. **16**, Valves of *Agrotis carolina*, McCabe slide 2663, North Carolina (Brunswick County, Green Swamp Preserve, 11 June 1991, S. Hall).

*A. buchholzi* include genitalic features as well as habitus. **Male genitalia:** The bases of the cucullar spines in *A. buchholzi* (Fig. 13) are mostly contiguous, those of *A. carolina* (Fig. 14) are typically widely spaced to the extent it would be possible to fit another spine in many of the spaces. A bulbous protuberance, near the basal end of the vesica, is opposite ( $180^\circ$ ) the basal cornutus in *A. carolina* and at more of a right angle ( $270^\circ$ ) to the basal cornutus in *A. buchholzi*. *Agrotis buchholzi* also has an indentation (a "valley") between the base of the vesica and the origin of the elongate distal portion of the vesica. This indentation is not seen in *carolina*. In 'perfect' eversions (some features can not be viewed if the vesica is accidentally pierced or severed short of the final narrowing resulting in a poorly inflated vesica) the most distal portion of the vesica displays a swelling before the final tapering (see Fig. 17). The apex of this swelling does not re-curve even as far as the bulbous vesical base in *A. carolina*, but re-curve to and through the length of the aedoeagus proper in *A. buchholzi*. Unfortunately this last feature has to be viewed during dissection as the true orientation is distorted by mounting in the viscous mounting medium. **Female genitalia:** *A. buchholzi* is proportionately smaller than *A. carolina* (photos are at the same magnification); appendix bursa swollen abruptly at tip in *A. buchholzi* (Fig. 20) that of *A. carolina* gradually enlarged (Fig. 19). There is a volume distinction as well. The swollen tip of the appendix bursa of *A. carolina* is approximately one third the volume of the bursa. The swollen tip of the appendix bursa of *A. buchholzi* is less than one-



FIGS. 17–18. Aedoeagus. **17**, Everted aedoeagus of *Agrotis buchholzi* (same data as Fig. 15). **18**, Everted aedoeagus of *Agrotis carolina* (same data as Fig. 16).

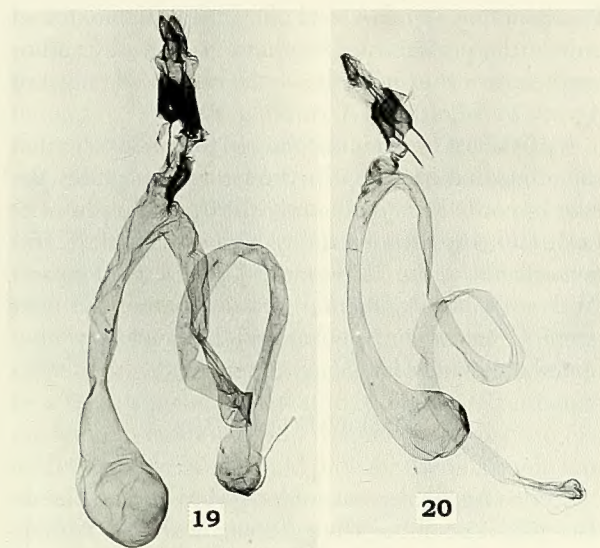
fifth the volume of the bursa. Very old and worn specimens possess particularly fragile appendix bursae and made for poor and nearly worthless slide mounts.

**Distribution.** We believe that *Agrotis carolina* will prove to be confined to eastern North Carolina or perhaps barely into South Carolina with its apparent food-plant (Radford et al. 1964). We have seen it from Brunswick, Pender, Onslow and Carteret Counties in the Outer Coastal Plain; Stephen Hall (pers. com. 2001) also has taken it in Hoke and Harnett Counties in the fall-line Sand Hills region of the inner coastal plain.

Populations of *A. carolina* in the outer coastal Plain are associated with *Pyxidanthera barbulata* var. *barbulata*, which is the foodplant of *A. buchholzi* in New Jersey. Specimens collected in the sand hills were associated with the endemic variety *brevifolia*, which differs in both its much more xeric sand ridge habitat and in morphology. Neither *Agrotis buchholzi* nor *A. carolina* occurs in the tiny pine barren remnant near Zuni, Virginia that harbors the only significant population of *Pyxidanthera* between New Jersey and North Carolina. This conclusion is based on repeated collecting efforts by both authors and the Virginia Natural Heritage Program.

**Biology of *Agrotis carolina*.** While this species has not been reared it is virtually certain that it feeds on the same plant as *A. buchholzi*, namely *Pyxidanthera barbulata* including variety *brevifolia*. As with *A. buchholzi*, *A. carolina* is taken virtually at will by placing





FIGS. 19–20. Female genitalia. **19**, *Agrotis carolina*, McCabe slide 2568, North Carolina, Pender County, 3.2 mi. W. Maple Hill, Angola Creek Preserve, 13 April 1991. **20**, *Agrotis buchholzi*, McCabe slide 2570, New Jersey, Burlington County, Atsion, 16 May 1985, D. Schweitzer.

light traps at patches of that plant. Unlike *A. buchholzi*, we are not aware of strays taken away from that plant.

Given the longer growing season in southeastern North Carolina one would expect three broods of *A. carolina* with the first two about a month earlier than the corresponding broods of *A. buchholzi* in New Jersey. Indeed there are broods peaking in April and June and an apparently more protracted third brood with dates from 1 August to 14 September (Stephen Hall pers. com. 2001). The first brood starts in late March, a bit earlier than might be expected considering the phenology of the two regions. The flight season of the spring brood of *A. carolina* overlaps substantially with the flowering period for *Pyxidanthera* while *A. buchholzi* flies after the foodplant has flowered. We thus suspect that adult *A. carolina* obtain nectar from the larval hostplant.

#### ECOLOGY OF *AGROTIS BUCHHOLZI*, *A. CAROLINA* AND FOODPLANT

*Pyxidanthera barbulata* is a prostrate mat forming plant of the largely arctic-alpine family Diapensiaceae, with showy flowers appearing in March or April. It grows in gaps in the shrub layer in open pinelands and flourishes for several years after fires on sterile white sands, such as the Atsion soil series in New Jersey. Such soils are generally very dry at the surface, but often, probably nearly always in North Carolina, they are moist just beneath.

Typical habitats for *A. buchholzi* are usually dwarf pine plains (Forman 1979) and recently burned pitch

pine lowlands. See McCormick (1970) or Forman (1979) for a general description of these communities. Large numbers can also be found around the edges of and to some extent in reedgrass (*Calamovilfa brevifilis*) savannas. Habitats for *A. carolina* include mesic wiregrass savannas, pine flatwoods and other frequently burned open pinelands. All normal habitats for both species can be characterized as fire disclimax coastal plain pinelands although the Atlantic City Airport habitat is maintained by annual winter cutting.

Fire frequencies vary from essentially a prescribed burn every winter at some North Carolina sites (e.g., formerly at Green Swamp) to only two or three wild fires per century in a few New Jersey sites. As a general rule one or more fires per decade will usually be required to maintain most high quality habitats in optimum condition for either species. Andrew Windisch (pers. com. to DFS 2001) suggests a regime of average to moderately severe wildfires at intervals of 10–30 years probably allows both *Pyxidanthera* and *A. buchholzi* to persist indefinitely in the core New Jersey Pine Barrens landscape (see also Windisch 1999). *Pyxidanthera* appeared to be still increasing on the Atsion burn scar in late 1989, over six years after the intense July 1983 fire, and had not declined noticeably by September 1991. By July 2001 it was still common in the more open areas but greatly reduced overall by heavy pine regeneration (DFS pers. obs.). Observations from Fort Dix suggest *A. buchholzi* numbers peak about one to five years after fires. Prescribed burning, as presently practiced in New Jersey, does not create suitable habitat for *A. buchholzi* since the sites involved already have a dense canopy which these light winter fires do not reduce.

There are no direct data on the immediate effects of fires on either *A. carolina* or *A. buchholzi* but both have been collected in numbers in spring following dormant season fires indicating obvious *in situ* survival as would be expected for underground larvae. While few insects from a centimeter below the soil surface to the tree tops would be likely to survive in duff to crown infernos in New Jersey wildfires, direct mortality of overwintering larvae of either *Agrotis* should be very low in most prescribed burns and in less intense wildfires. However, captive *A. buchholzi* larvae moved to the soil surface to pupate by late March (*A. carolina* probably does so in February), which could leave them vulnerable to intense wildfires during the spring fire season.

In addition to direct mortality larvae would starve and/or females be forced to emigrate if fires killed the *Pyxidanthera* foliage. Top kill of this plant was observed in March following winter burns in at least one North Carolina site (DFS pers. obs.), but not at some



others. Top kill is common in New Jersey fires. Most patches resprout after light fires, and light fires may well stimulate germination. Summer fires, which occur in very frequently burned parts of Fort Dix, may burn slowly along the ground surface or through the shrubs and consume only the outer parts of the apparently succulent *Pyxidanthera* mats, leaving the centers intact. Larvae in these patches would have good survival. Such fires are not now typical elsewhere in the range of *A. buchholzi*, in part because of accumulation of more fuel between infrequent fires. They may be more typical in *A. carolina* habitats and may also have been more typical in pre-settlement New Jersey. Unburned refugia should always be left in any prescribed burns and are clearly needed with some of the hotter New Jersey wildfires.

**Associated species.** Both of these *Agrotis* occur with other rare and extremely range-restricted Lepidoptera. *Agrotis buchholzi* usually occurs with some or all of the other the Pine Barrens endemics and near endemics. *Crambus daeckellus* Haimbach (Pyralidae) is easily found in its habitats on Ft. Dix and Lakehurst Naval Air Station within five meters of patches of *Xerophyllum asphodeliodes* (L.) Nutt. (Liliaceae) (DFS pers. obs.) but has not been taken elsewhere since before 1960. Two still unnamed *Crambidia* (Arctiidae, Lithosiinae) species described and keyed by Franclemont in Forbes (1960) bring the list of apparent Pine Barrens endemic moths to four species. Both *Crambidia* occur at some *A. buchholzi* sites. One of the *Crambidia* is common and widespread in the region, while the other may prefer habitats similar to those used by *A. buchholzi*.

*Spartiniphaga carterae* Schweitzer (Noctuidae), which is a borer in the grass *Calamovilfa brevipilis* (Torr.) Scribn., and an unnamed geometrid consistently misidentified (e.g., Forbes 1948) as *Cyclophora* or *Cosymbia culicaria* (Guenée)<sup>1</sup>, which apparently feeds mostly on *Leiophyllum*, have ranges similar to the combined range of *Agrotis buchholzi* and *A. carolina* and are often microsympatric with them. *Agrotis buchholzi* was collected in the same light trap sample as a paratype of *Abagrotis cryptica* LaFontaine (known from only two specimens from the New Jersey Pine Barrens and one from Michigan). The now severely imperiled venus flytrap cutworm, *Hemipachnobia subporphyrea* (Walker), is essentially endemic to the eastern part of the range of *A. carolina*. With four and two respectively New Jersey and North Carolina appear to lead eastern US states in terms of endemic

Lepidoptera species. A total of eight species are found only in the pinelands of southern New Jersey and/or southeastern North Carolina—the combined ranges of *Agrotis buchholzi* and *A. carolina*.

A partial list of other uncommon to rare species that sometimes co-occur with *A. buchholzi* includes the now imperiled *Atrytone arogos arogos* (Boisduval & LeConte), *Hesperia attalus slossonae* (Skinner), *Hypomecis buchholzaria* (Lemmer), *Heterocampa varia* (Walker), *Catocala herodias gerhardi* Barnes and Benjamin, *Catocala jair* Strecker, and the previously mentioned unnamed *Mesembagrotis* species.

#### CONSERVATION STATUS

*Agrotis buchholzi* was under review on the Candidate (C2) List of the United States Fish and Wildlife Service under the United States Endangered Species Act as published in the Federal Register on 15 November 1994. Since the range was given as New Jersey and North Carolina, this listing included *Agrotis carolina*. The C2 list was abandoned for political reasons in the mid-1990's and no decision was made on these species.

At present neither *Agrotis buchholzi* or *A. carolina* are in immediate danger of extinction but given present trends of fire suppression in New Jersey and outright habitat loss and fragmentation in North Carolina, and dependence on fortuitous management practices in both states, neither species can be considered secure. Either could become threatened in the foreseeable future. Very little, if any, non-military land is appropriately managed for *A. buchholzi* and, in the absence of appropriate management, the fire trends discussed below threaten its long-term survival. Both species have extraordinarily small ranges for moths, each being known from only from a single state and three and six counties respectively. *Agrotis buchholzi* is still locally common in the northern half of the New Jersey Pine Barrens in Burlington and Ocean Counties. It does not appear to occupy isolated, largely roadside, patches of the foodplant in Monmouth County or around Batsto in southern Burlington County.

A very substantial portion of the total range of *A. buchholzi* is on lands owned by the State of New Jersey and the United States Military Services. Nearly all of the range of *A. buchholzi* falls under the jurisdiction of the New Jersey Pinelands Commission, which conveys some level of habitat protection but no assurances of management. The Military, The US Forest Service, the state of North Carolina, and The Nature Conservancy own substantial habitats for *A. carolina*. Most of the original habitat for *A. carolina* has been developed

<sup>1</sup> Based on examination of the types in the United States National Museum by DFS.



or converted to agriculture or pine plantations while most of the range of *A. buchholzi* still supports more or less natural, but increasingly fire-suppressed, vegetation.

By far the largest populations (based on numbers in trap samples and extent of optimum habitat) of *A. buchholzi* are on Fort Dix and are maintained by fires from military exercises with some prescribed burning. Recent fire intervals have ranged from less than a year to three years in much of this habitat, with a few parts unburned for five years or longer. Any major curtailment or cessation of military activities on Ft. Dix would be a serious potential threat to *A. buchholzi*, although moderate relaxation of fire frequency (perhaps to two or three per decade) would probably benefit some rare associates, especially *Atrytone arogos arogos*.

Most of the range of *Agrotis buchholzi* is relatively undeveloped, with vast tracts of forest, woodland, scrub and substantial berry farming. Wildfires are responsible for the existence of most remaining habitats for *A. buchholzi* and several other specialized Pine Barrens Lepidoptera. Givnish (1981), Forman and Boerner (1981), Buchholz and Zampella (1987) and Windisch (1999) all document that acreage burned by wildfires has declined in recent decades, and Harshberger (1917) describes a fire swept, cut over, and much less forested region than is present now.

The location in the West Pine Plains where Madenjian and Schweitzer collected *A. buchholzi* in 1977 and 1980 has since closed in noticeably. Parts of the Plains have now not burned for 50–70 years instead of the optimum 5–15 year interval, resulting in closed woody strata of shrubby pines, oaks and heaths, and a marked decline in *Pyxidanthera* and subshrubs such as *Corema conradii* Torr. and *Arctostaphylos uva-ursi* (L.), forbs, and native grasses (Windisch 1999). When fires finally do occur after prolonged (>30–40 years) exclusion they tend to be extremely severe and may reduce or eliminate *Pyxidanthera* plants and seedbanks (Windisch 1999). The increased time between and increased severity of fires are leading to a loss of this plant and its seeds in some areas of the Pine Barrens, even in the core, as well as in peripheral areas (Windisch 1999). Nevertheless, intervening landscapes between major *A. buchholzi* habitats still typically do have some *Pyxidanthera* at least along sand roads and in disturbances, and still experience occasional wildfires on the scale of a few hundred to a few thousand hectares.

While metapopulation dynamics are almost certainly deteriorating, females have been collected about one and three kilometers out of habitat and so do disperse. Metapopulations probably still function except in eastern Atlantic County. Metapopulation collapse is

very possible in the next few decades without appropriate management practices or an increase in moderate intensity wildfires. Since wildfires occasionally affect thousands of hectares (maximum single fire recorded about 38,000 hectares in April–May 1963), *A. buchholzi* could become quite imperiled by any major range contraction or fragmentation which would leave it at risk of having a single hot fire burn all of its habitats simultaneously.

*A. carolina* is more widespread (at least six counties in two separate areas) but its major habitats are within a matrix of a much more intensively developed and agricultural (including pine farming) landscapes and the foodplant is much more localized than in New Jersey. *P. barbulata* variety *barbulata* is currently considered as uncommon (S3) by North Carolina Natural Heritage Program and the endemic Sand Hills variety *brevifolia* is considered Endangered (S1). At present all major habitats with the foodplant that have been checked still have the moth. However, it was not found at two small previously fire-suppressed remnant *Pyxidanthera* sites in Weymouth Woods State Natural Area in Moore County, within 20 kilometers of the Ft. Bragg population (Stephen Hall pers. com. May 2001). Large tracts probably supporting metapopulations on thousands of hectares of habitat exist, including in the Croatan National Forest, some military lands such as Camp Lejeune, Fort Bragg, and MOTSU, Green Swamp Preserve, and Holly Shelter State Gamelands, but most or all are probably functionally isolated from others.

*Agrotis carolina* and its habitats are being perpetuated by current prescribed burning practices, usually dormant season burns, on actively managed state and private conservation lands as well as by combined accidental and prescribed fires on military lands. Tree cover in these habitats tends to be naturally sparse. Perhaps selective thinning combined with prescribed burns would restore *A. buchholzi* habitats in New Jersey.

We recommend that managing agencies for lands harboring *Agrotis buchholzi* or *A. carolina* cooperate with future investigators, including amateur collectors, to the extent practical. Both species generally occupy habitats of hundreds to thousands of hectares and are among the more numerous Noctuidae in them and so are obviously not at risk from ordinary collecting methods. It is specifically recommended that where collecting permits are required on certain state or federal lands, they be made readily available with minimum restrictions other than reporting requirements. Reports from collectors would provide useful updates on the status of *A. buchholzi* and *A. carolina* and repeated failures to find these easily sampled moths would be a good indicator of declines. The only known



population of either species that might be small enough to be vulnerable to occasional blacklight trapping is the isolated one near Atlantic City Airport and current inventory efforts there (by DFS) aimed at other taxa avoid its limited habitat during the flight season.

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## LIFE HISTORY AND IMMATURE STAGES OF *CHLAMYDASTIS PLATYSPORA* (ELACHISTIDAE)

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**ABSTRACT.** The natural history of *Chlamydastis platyspora* Meyrick (Elachistidae) is described from the cerrado ecosystem (savanna-like vegetation) in Brasília, Distrito Federal, Brazil, and also from specimens reared in the laboratory. The larvae are external folivorous feeders restricted to the host plant *Roupala montana* Aubl. (Proteaceae). The life cycle from egg to adult lasts about 4.5 months. In the natural cerrado ecosystem *C. platyspora* is bivoltine, the first generation occurring from November to April (wet season) and the second from May to October (early dry season to beginning of the wet season). The immature stages are described. Egg, larval head capsules, last larval instar, pupa, and adult male and female are illustrated. Morphological modifications in the mandible of the third instar larva, chaetotaxy of the last larval instar, and male and female genitalia are also described.

**Additional key words:** Brazil, cerrado, host plant, natural history, *Roupala*, Proteaceae.

*Ptilogenes platyspora* and *P. amblystoma* were described by Meyrick in 1932 and 1936 respectively. The female type of *P. platyspora* was collected from Araras (São Paulo, Brazil) and deposited in the Naturhistorisches Museum (NM), Vienna, Austria. The type of *P. amblystoma*, also a female, was collected from Rio Grande do Sul, Brazil and deposited in the Institut für Pflanzenschutzforschung, Eberswalde (IP), Germany. Busck (1934) transferred these species to *Chlamydastis* (Elachistidae, Stenomatinae) and Becker (1984) recognized that *C. amblystoma* is a junior synonym of *C. platyspora*.

Besides what is described above, the only information known about *C. platyspora* is that it is restricted to the host plant *Roupala montana* Aubl. (Proteaceae) in the cerrado of Brasília, Brazil (Diniz & Morais 1995). Therefore, this research constitutes the first study of the natural history of a species in this genus (with 81 described species) (Hogue 1984). The objectives of this study are to describe the immature stages (egg, larva, pupa) of *C. platyspora* and the life cycle in the field. The male genitalia are also described to facilitate identification of adults by future workers.

### MATERIALS AND METHODS

The descriptions of immature stages and adult genitalia were based on specimens reared in the laboratory. To obtain eggs, six pupae (three males, and three females) of *C. platyspora* were collected from several plants of *R. montana* in an area of cerrado (sensu stricto Goodland 1971), in the Brasília University Experimental Farm (Fazenda Água Limpa-FAL) (15°55'S, 47°55'W) in Brasília, Distrito Federal, Brazil, and maintained in a rearing cage until adult emergence. Leaves of the host

plant *R. montana* were supplied with the purpose of simulating natural conditions and to serve as substrate for oviposition. To maintain the swelling turgidity of the leaves, the petioles were immersed in moist cotton. Fresh leaves were supplied every two days.

All observations and measurements were made with a stereomicroscope using an ocular micrometric scale or a millimeter scale paper. The following measurements were taken: eggs (length and width), head capsules of the different instars (distance between the second stemmata), body length of the last instar larva and pupa (from head vertex to end of last abdominal segment), pupal cocoon (length and diameter), and the length of the right wing of the adults.

The mandible of different instar larvae, larval exoskeleton of the last instar, and the adult genitalia were preserved in permanent slides and examined under compound and stereo microscopes. The material was heated in a 10% potassium hydroxide (KOH) solution. The terminology used follows Klots (1970) and Stehr (1987). Camara lucida illustrations were made using a compound microscope (Zeiss ULTRAPHOT III). Voucher specimens were deposited in the Entomological Collection of the Zoology Department of the University of Brasília, DF, Brazil.

The field study was carried out in an area of approximately 2 ha of cerrado sensu stricto. The life cycle under natural conditions was determined by searching for eggs, larvae, or pupae of *C. platyspora* on 300 to 500 plants of *R. montana* monthly, from November 1999 to October 2000. The behavior of the larvae of *C. platyspora* was monitored twice a week using 15 marked plants on which eggs or larvae were present and followed until the completion of the life cycle.



## RESULTS

**Description of the immature stages.** **Egg:** pale yellow, transparent, ovoid, flattened, 3.0–4.5 mm length (mean = 3.79 SD = 0.5) and 2.0–2.5 mm width (mean = 2.25 SD = 0.2). Chorion sculptured with fine minute ridges. Egg with changes of coloration from yellow to brown, due to the embryonic development of the larva (Fig. 1A).

**Larva: First instar** (n = 10), head dark chestnut, body integument greenish yellow with brownish-red transverse stripes; head capsule 0.3–0.5 mm wide (mean = 0.4 SD = 0.1) (Fig. 1B); mandible with five incisive "teeth" and four transverse furrows on the concave oral surface (Fig. 2A). Setae clear yellow, located on large body pinnacles. **Second instar** (n = 4), head, body integument and setae as in the first instar; prothorax with several brownish spots, a yellow stripe in the anterior margin, and a dark chestnut prothoracic shield. The head capsule is 0.5–0.8 mm wide (mean = 0.63 SD = 0.1) (Fig. 1B). Mandible morphology as in the first instar. **Third instar** (n = 2), head and setae as in previous instars. Body integument with a conspicuous reddish longitudinal lateral spiracular stripe from the prothorax to A10. Head capsule 0.9–1.2 mm wide (Fig. 1B). Morphology of the mandibles as previous instars. **Fourth instar** (n = 2). Head, body integument, and setae as in the third instar. Head capsule 1.2–1.9 mm in width (Fig. 1B). Mandibles lacking "teeth", smooth and bearing a reinforced furrow finishing in a small dorsal lobe above the retinacular seta. Oral surface concave and smooth (Fig. 2B). **Fifth instar** (n = 2). Head and body integument as in the previous instar (Fig. 1C). Body length: 19–20 mm. The integument of the larval cuticle (Fig. 2C), including the pinacula, presents a granular texture when observed under high magnification. Head capsule and anal plate dark brown, with a reticulate texture. Head capsule 2.0–2.3 mm wide (Fig. 1B). Mandibles as in the fourth instar. Hypopharynx with an elongate spinneret and submental pit present. Generation time (egg to adult) of *C. platyspora* in the laboratory lasted 136 days (4.5 months).

**Chaetotaxy. Thorax: Prothorax:** Three dark chestnut pinacula on prothoracic shield. Three setae of group L (lateral) extended over the anterior-ventral of the spiracular pinacula. **Mesothorax:** A sub dorsal micro seta on a pinaculum in the ante-dorsal edge of the mesothoracic segment. Two dorsal pinacula without setae differ in color, one being lighter than the other. Seta D2 (dorsal) four times the length of D1; SD1 and SD2 (sub dorsal) group on a single pinaculum. **Metathorax:** Setae position similar to that of the mesothorax, differing only by the presence of the dorsal and sub dorsal micro setae. Thoracic legs well developed and tarsal claws with the pre-tarsal setae disposed as cilia (see Stehr 1987:384). **Abdomen:** A1–A5 with a dorsal micro seta and two D setae obliquely placed on a prolonged pinaculum. A6 and A7 with two SD setae and a ventral seta on pinaculum (V), and A6 with a non-sclerotized round area in the posterior part of the pinaculum. A8 with the SD1 seta in the ante-dorsal position to the spiracle and A9 with setae D1 and D2 in separate pinacula. Prolegs on A3–6; crochets uniserial and biordinal disposed in circles (see Stehr 1987:384).

**Larval shelters.** Larvae of all instars construct shelters by binding together two leaves of the host plant and frass with silk. During larval development at least four of these shelters are constructed. The last instar larva builds a large shelter of leaves where pupation occurs.

**Cocoon.** The cocoon is dark chestnut, ovoid, with a thick wall composed of frass and silk and an inner layer of silk. Females' cocoons 42–55 mm length (mean = 48 SD = 4.7) and 7–19 mm width (mean = 2.8 SD = 2.8) (n = 11) and the males from 33–47 mm length (mean = 41.2 SD = 5.2), and 11–17 mm width (mean = 14.6 SD = 2.5) (n = 5).

**Pupa.** Wrinkled texture and variable coloration from clear red brown to dark brown. Female (Fig. 1D) from 18–20 mm length (mean = 19.3 SD = 0.9) (n = 8) and male (Fig. 1E) 16–17 mm (mean = 16.6 SD = 0.5) (n = 5). **Abdomen.** Fifth, sixth and the seventh abdominal segments are immobile; cremaster ventrally rounded, with two short setae on small lateral tubercles.

**Adults.** The male's wings have the same color and pattern as the female, as described by Meyrick (1932). Male forewing length 13–

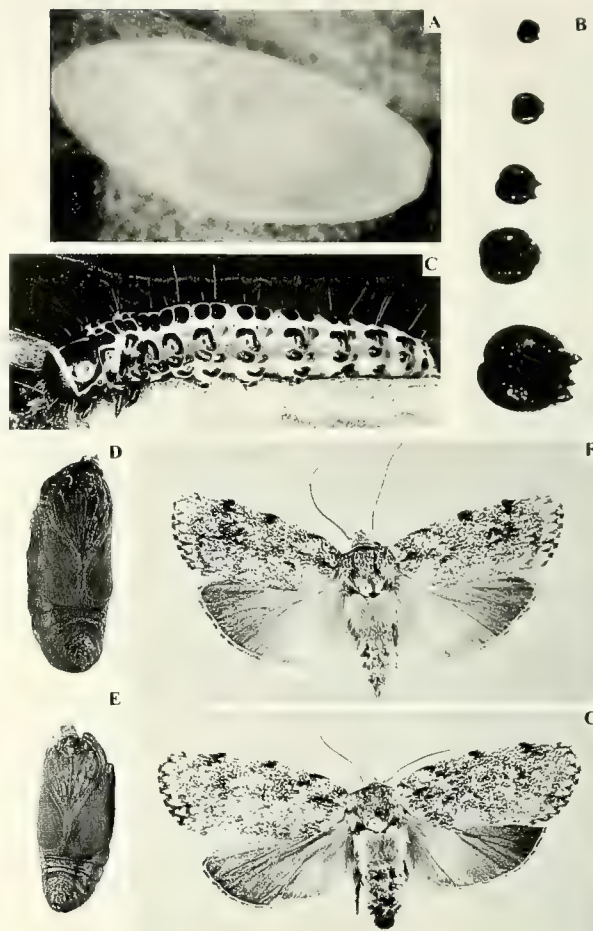


FIG. 1. *Chlamydistis platyspora*. A, Egg; B, Head capsules from 1st to 5th instars; C, Larva of the last instar; D, Female pupa; E, Male pupa; F, Male adult and G, Female adult. (Color illustrations can be found at [www.unb.br/ib/](http://www.unb.br/ib/))

16 mm (mean = 1.5 SD = 0.13, n = 7) (Fig. 1F) and females 17–21 mm (19 SD = 0.13, n = 10) (Fig. 1G).

**Female genitalia** (Fig. 2D). Papillae anales formed into large compressed pads; eighth sternum rectangular, with ante-dorsal rift invaginate forming a pair of round bags, ornamented with numerous fine hooks; posterior apophyses curved close to the base and slightly longer than the anterior; antrum wide sclerotized; seminal ductus bursal short, spinulate; inception of ductus seminalis on anterior part of antrum; corpus bursae elongate, signum plate-like and spinulate.

**Male genitalia** (Fig. 2E). Uncus curved, with the apex rounded and narrowing from the base; gnathos poorly developed, slightly curved and medially spinose. Costa of the valves with round termination, cuculus thoroughly rounded, with piliform setae on the inner surface, intermixed with setal with palmate apices (Fig. 2F). Vinculum truncate ventrally; juxta developed. Adeagus short, cylindrical and slightly curved; the vesica with an irregularly round cornutus.

**Life cycle in the field.** Initially, eggs were found in the field on 23 December 1999 (Table 1). The larvae occurred from January to March, and the pupae from April to May. By 19 May 2000 all adults had emerged from their cocoons. Thus, the first generation occurred from December to May, and corresponded with the



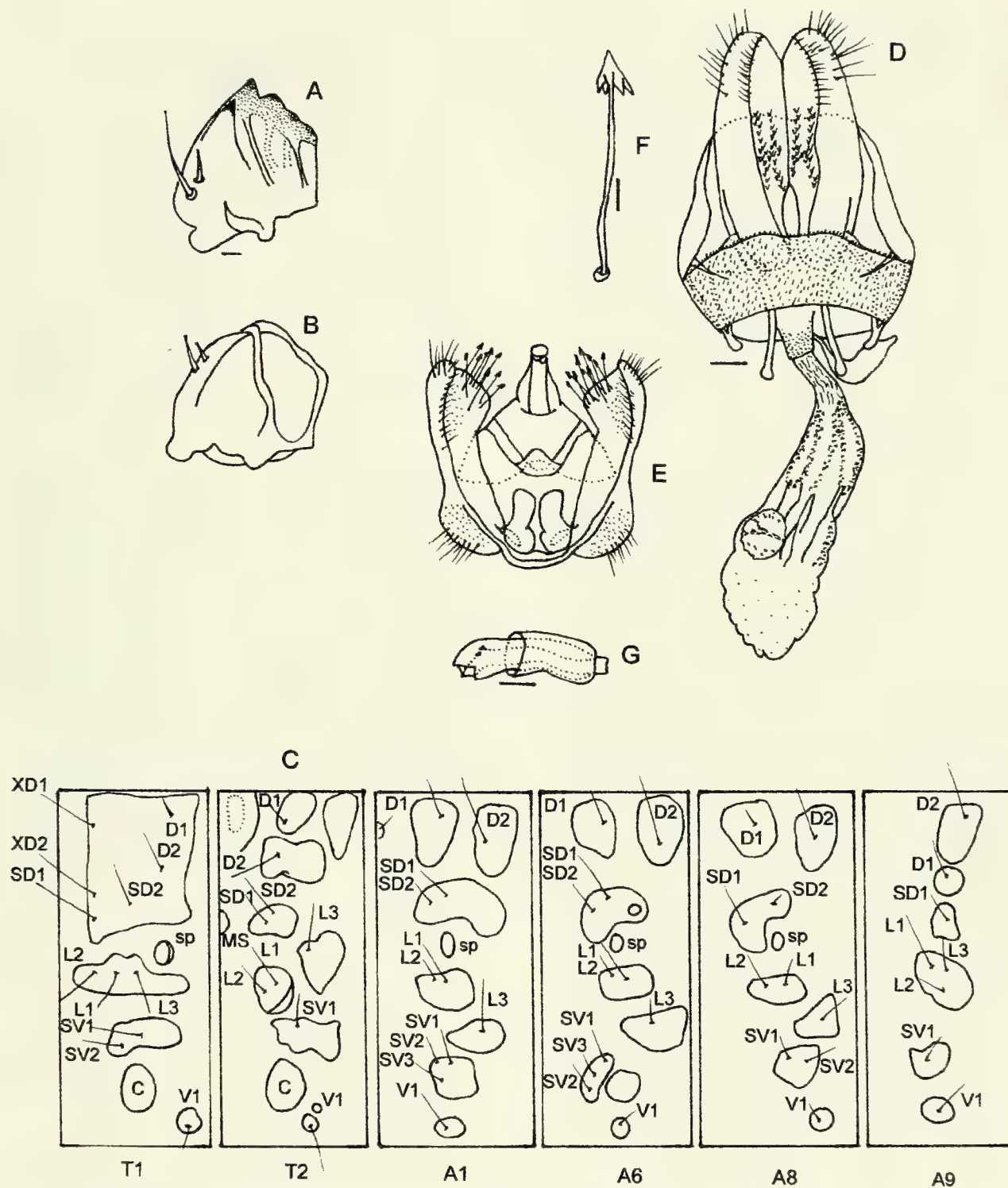


FIG. 2. Structures of the larvae and adults of *Chlamydastis platyspora*. **A**, Mandible of the larvae from 1st to 3rd instars; **B**, Mandible of the larvae of the 4th and 5th instars; **C**, Chaetotaxy of the 5th instar; **D**, Female genitalia; **E**, Male genitalia; **F**, Details of the setae of the cucullus; **G**, Aedeagus. Scale bars represent the following values: **A** and **B**, 35.7  $\mu$ m; **D** and **E**, 0.4 mm; **F**, 35.7  $\mu$ m and **G**, 89  $\mu$ m.



TABLE 1. Number of plants inspected from November/1999 to October/2000 and the immature stages found.

Months	Plants examined			Number of immature			
	Total	Plants with immatures		Eggs	Larvae	Pupae	Total number of immatures
		number	%				
November	400	0	0	0	0	0	0
December	432	1	0	6	0	0	6
January	486	13	2.7	0	29	0	29
February	550	16	3.0	0	50	0	50
March	408	26	6.3	0	27	0	27
April	341	23	6.7	0	0	33	33
May	400	13	3.4	25	0	19	44
June	400	76	1.0	0	159	0	159
July	300	41	13.7	0	81	0	81
August	300	56	18.7	0	83	0	83
September	300	39	13.0	0	68	0	68
October	300	39	13.0	0	60	1	61
Total	4617	343	7.4	31	557	53	641

period from the middle of the wet season to dry season. The second generation began in early May, the larvae occurred from June to October (Table 1). We observed pupae on 10 October 2000, corresponding to the period between the dry season to wet season.

**Behavior of the larvae of *C. platyspora*.** In the laboratory, we observed 6 and 25 eggs laid in December 1999 and May 2000, respectively. They were laid singly, on the adaxial surface of the mature leaf of *R. montana*. First larvae were observed on 11 January 2000. After hatching, the larvae moved to another leaf on the same branch, where they fed and built their initial shelter. Frequently, newly hatched larvae remained in small groups from three up to five individuals; however, some larvae remained solitary. Larvae built their shelters by attaching two leaves together with silk or by folding one leaf and incorporating a protecting frass layer intertwined with the silk threads inside. First instar larvae scrape the abaxial leaf surface to the mesophyll. Solitary larvae built shelters in a similar way, but with a single chamber. Later instar larval (3–5) are solitary and built shelters in a similar way as does the first instar, except these lack the inner protective silk layer. In addition, later instar larvae exhibit aposematic colors and, as a reaction to any aggression or disturbance, regurgitate a substantial amount of a greenish liquid. As larvae mature, they built at least four larger shelters, each of them with a thicker wall. The leaves surrounding the shelters become more and more separated in successive shelters due to an increase in size of the larvae. Fourth instar larvae change their feeding habit from scraping the abaxial leaf surface within the shelter to consuming the whole leaf, and foraging outside of the shelter during the day. Fifth instar larvae construct a large cocoon, with thick walls covered with a dense layer of silk, leaves and frass.

## DISCUSSION

The flattened egg observed for *C. platyspora* seems to be common among moths. Pertenson (1965) described flattened eggs for two species of moth of the family Tortricidae (*Carpocapsa pomonella* (Linn.) and *Acleris variana* Fern.). Scoble (1995) refers to them (present in Pyralidae moths) as being important in protection against natural enemies because they are unnoticeable on the substrate surface, and cannot be easily seen by predators.

Factors that affect oviposition strategies are numerous; for instance density of predators and parasites (Stamp 1980), host scarcity (Benson et al. 1975, Jones 1977), and flight inhibition caused by adverse climatic conditions (Courtney 1984). The low number of eggs observed in this study does not allow us to discuss the above arguments regarding the oviposition strategies of *C. platyspora* females. However, the host plant (*Roupala montana*) in our study area is very abundant so host plant scarcity was not an issue. Because a high mortality rate of *C. platyspora* larvae was observed in the field, only 53 of 557 reached the pupal stage (Table 1). It can be assumed that for this species, in the cerrado, others factors such as predators, parasites, and adverse climatic conditions play a more important role in controlling the size of larvae populations than the plant resource.

The larval stage was the longest stage of development. Larvae exhibited several different behaviors, such as: construction of shelters, aggregation in the first instar, changes in feeding habits from scraper to cutter, acquisition of aposematic colors from the third instar, and the regurgitation reaction when agitated. The first two behaviors are common among Lepidoptera; for example, see *Omphalocera munroei* Mar-



tin (Pyrilidae) which builds shelters by tying leaves of *Asimina* spp. (Annonaceae) (Damman 1987).

Variation of the mandible morphology of larvae (Fig. 2A, B) was already observed for other moth species such as *Heterocampa oblique* Packard and *Crinodes besckei* (Hübner) (Notodontidae) (Godfrey et al. 1989). The authors suggested that these mandible morphological variations have two functional purposes: allowing the opening of the egg chorion, and better scraping of the leaf while feeding. The scraping habit is very advantageous for small larvae due to the limitation of the size of the bite relative to leaf thickness. According to Bernays and Chapman (1994), many Lepidoptera feed on mature leaves and in that case, the first instar larvae may not have the size or the necessary strength to pull up pieces of leaf. The morphology of the mandible found in the fourth larva instar (Fig. 2B) is similar to that of other moths as, for example, in species of Saturniidae. This morphology is adapted to cut the mature leaves of the plants, which they usually feed on. The convergences of characters are an indication of the adaptive function (Bernays 1991).

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## DESCRIPTION AND LIFE HISTORY OF *PEDALIODES ZINGARA*, A NEW SATYRINE SPECIES FROM COLOMBIA (NYMPHALIDAE)

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**ABSTRACT.** We describe the immature stages and the adult (male and female) of *Pedaliodes zingara*, a new species of pronophiline satyrine from the Cordillera Occidental of Colombia. Bionomics of the species and its possible congeneric relationships, as well as its breeding potential and pattern of egg production, are discussed.

**Additional key words:** biogeography, life cycle, Neotropics, Pronophilini, South America.

**RESUMEN.** Se describe los estadios inmaduros y el adulto (macho y hembra) de *Pedaliodes zingara*, nueva especie de satírido pronofilino de la Cordillera Occidental de Colombia. Se aporta información bionómica sobre la especie y se discute sobre las posibles relaciones con sus congéneres, su potencial reproductivo y su patrón de producción de huevos.

**Palabras clave adicionales:** biogeografía, ciclo de vida, Neotrópico, Pronophilini, Sudamérica.

During the last four decades, the Neotropical Satyrinae have once again drawn the attention of lepidopterists. The systematics of the subfamily underwent substantial changes (Forster 1964, Miller 1968, Viloria in press), and a considerable number of descriptions of recently discovered taxa has been published. However, the fundamental knowledge of the biology of this group of Lepidoptera is limited due to the scarcity of hostplant identifications and developmental observations (Viloria in press, Beccaloni et al. in press). The butterflies of the genus *Pedaliodes* Butler may well illustrate these assertions. They are, within the Satyrinae, a prominent focus of current taxonomical progress (e.g., Adams 1986, Pyrcz & Viloria 1999, Viloria & Pyrcz 2000), but their biology is so poorly studied that not even one complete life cycle has hitherto been described (see discussion).

Sometimes morphological divergences among butterfly species are more marked on immature stages than in adults. Such appears to be the case in some nymphalid genera like *Cissia* (especially the 'confusa' group, sensu Singer et al. 1983), *Adelpha* (Aiello 1984) and *Calisto* (Sourakov 1996, 1999), in which the knowledge of life cycles has contributed to the determination of taxa. Yet, it is not known whether those species of *Pedaliodes* that are difficult to separate by features of wing pattern or male genitalia show substantial differences in their early stages. Furthermore, attempts to reveal the phylogenetics of *Pedaliodes* are entirely based on adult morphology, whose character sets are limited compared with the apparent species richness of the clade (Viloria 1998). In other words, there are so many species, so few useful characters,

and so little variation within most of these characters, that one wonders whether it is possible to get a unique matrix representing the character states for each and every known species of *Pedaliodes*. Should it be feasible to produce a reliable phylogeny based on adult characters, then it would necessarily be just a preliminary one, as the discovery of additional (perhaps unexpected, and certainly new) features from the life history of these insects might render another scenario. Therefore, general interest in the study of the immature stages of the Neotropical Satyrinae is growing (see for instance, Freitas 2002, 2003).

Research on the biology of the insect fauna associated with montane woody bamboos of the genus *Chusquea*, conducted by the senior author in the Western and Central ranges of the Colombian Andes, has for the first time yielded accurate information on the life cycle of several species of butterflies (Morphinae, Satyrinae) and skippers (Hesperiidae) (Heredia & Alvarez-López in press, and unpubl.). One of the satyrines whose cycle was observed entirely from egg to imago was recognized as an undescribed species of *Pedaliodes* Butler, which was already known to one of us (ALV) by old museum specimens. Both the species and its life history are described here.

### MATERIALS AND METHODS

Standard systematic work was based on individuals collected as adults and laboratory reared adults from eggs and larvae picked up in the type locality (now deposited in the collections of the Museo de Entomología [MEUV], Universidad del Valle, Cali, Colombia, and in the private collection of M. Dolores





FIG. 1. Adults of *Pedaliodes zingara*; **a**, Dorsal view of male Holotype, Zingara, Municipio de Cali, Departamento del Valle del Cauca, Colombia, 2000 m, 03°32'23"N, 76°36'16"W, adult emergence date 16 October 1999, M. D. Heredia (MEUV); **b**, The same, ventral view; **c**, Dorsal view of female paratype, same locality, adult emergence date 13 October 1999, M. D. Heredia (MEUV); **d**, The same, ventral view.

Heredia (MDH), Cali), and on specimens from the entomological collections of the Natural History Museum, London, UK (BMNH), the State Zoological Collections of Munich, Germany (ZSBS), the Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá (ICN), and the private collection of the Constantino family (CFC) in Cali.

The type locality, Finca Zingara, is a small farm within a wider study area (1900–2200 m), which is located 4 km north of “El Dieciocho” (km 18 of the road from Cali to Buenaventura) on the way to Pavas, eastern slope of the Cordillera Occidental, Corregimiento de La Elvira, Municipio de Cali, Departamento del Valle, Colombia. It is included in the “lower montane moist forest” of Holdridge’s Life Zones system (Espinal & Montenegro 1963). The local vegetation is composed by cloud forest patches, more or less disturbed, surrounded by suburban land properties for recreational and/or low intensity forestry, dairy, and agricultural activities.

Life history data were gathered through direct observation of adult females and larvae in captivity. Larvae and eggs independently obtained by visually searching the bamboo (*Chusquea*) clumps at the type locality, were selected and transferred to rearing bottles in the laboratory in Cali. Larvae were bred at controlled room temperature of 20–24°C, with a photoperiod of 12:12. Hostplant stock was kept fresh up to two weeks wrapped in damp paper towels in a refrigerator. Larval food was replaced daily, and observations were processed on the same basis. Adults in captivity were fed ad libitum a 20% honey-water solution three times per day. Oviposition was induced by placing the female in a plastic cage (14 × 16 cm) together with fresh *Chusquea* stems and leaves.

Early stage individuals were described and measured in vivo, in each case just after hatching or molt, using a stereomicroscope (15–20×) equipped with reticules of 0.1 and 0.05 mm. Adults, epicrania and exuviae of the pupae were preserved in the collection of one of the authors (MDH). Specimens of the hostplants were deposited in the Herbarium of the Universidad del Valle, in Cali.

#### SYSTEMATICS

##### *Pedaliodes zingara* Heredia & Viloria, new species

(Figs. 1, 2, 3, 4, 5)

[*Pedaliodes* sp. nov. 2 Viloria MS]; Viloria, 1998:297–298.

[*Pedaliodes phrasiclea* Grose-Smith; Pyrcz, 1999:355, 356; Viloria & Pyrcz, 2000:97; Viloria et al., 2001:40 (misidentifications, in part)]

**Diagnosis.** *Pedaliodes zingara* could be confused with *P. phrasiclea* Grose-Smith, 1900, *P. pisonia* (Hewitson, 1862), and *P. canela* Pyrcz & Viloria, 1999, the latter recently recorded from the Pacific slope of the Western Andes. *Pedaliodes canela* flies above 2000 m and is similar in size to *P. zingara*. However, *P. canela* does not have the ventral reddish suffusion on the anal region of the hindwing. On the other hand, *P. pisonia* shows a similar wing pattern, but it is smaller than *P. zingara*, and it is almost certainly restricted to Venezuela (Viloria et al. 2001). This new taxon has been confidently recorded on the Western Andes, but there are two dubious museum records from the Eastern Andes in the Bogotá area. Adults fly between 1800 and 2200 m, which means that it can overlap altitudinally with *P. phrasiclea*, which also ranges in the Western Andes between 1200 and 1800 m. and often bears a reddish suffusion on the anal region of the hindwing verso. Nevertheless, male genitalia of these two species show



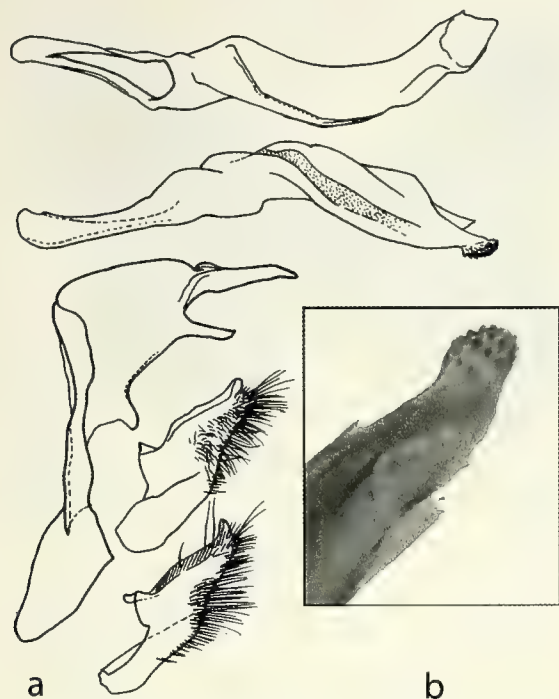


FIG. 2. a, Male genitalic armature of *Pedaliodes zingara*, new species. Valvae (right) and aedeagus (above) have been removed from their original positions to allow more informative views. Aedeagus has been drawn in dorsal (above) and lateral view (below); b, Close up of the spiny process of the apical extremity of aedeagus.

clear differences in the caudal extremity of the aedeagus, in the shape of the saccus, in the junctions of the uncus and the tegumen (which has a slight prominence in *P. zingara*), and in the distal process of the valvae.

**Description.** Male (Figs. 1a, b): FWL 30.4 mm ( $n = 4$ ,  $SD = 1.03$ ). Head: Antenna reaching to half costa, brown with beige scales dusted along dorsal and ventral surfaces, club gradually formed, cylindrical; eyes dark brown with black hairs; palpi externally with light band at base, internally with sparse light-brown hairs, black hairs distally. Thorax: dark brown, dense brown hairs laterally; second and third pair of legs brown, with reddish hairs only on femorae. Abdomen: brown, slightly paler ventrally. Wings: Forewing outer margin smooth, slightly scalloped in hindwing. Both wings with some beige scales on the fringes. Dorsally dark and bright brown, forewing postmedial and marginal areas slightly paler. Hindwing hairy on anal region and discal cell. Androconial patches similar to those of *P. canela* (Fig. 4). Forewing ventral surface dark brown, lighter band from postmedial region to outer margin, chestnut on apex and subapical region; lighter brown on two portions of discal cell (distal and medial), as well as on anal margin; 2 to 3 minute submarginal white dots in cells R5, M1 and M2, respectively. Hindwing ventral surface dark brown, lighter band from postmedial region to outer margin, which is chestnut; submarginal dots in cells Rs, Cu1 (larger, circled with black) one each, and two in Cu2; anal region with a reddish suffusion, which reaches vein Cu2 in its wider portion. Armature of the genitalia illustrated in Fig. 2.

Female (Figs. 1c, d): FWL 31.3 mm ( $n = 4$ ,  $SD = 1.11$ ). Similar to male but larger; background ventral color lighter and more chestnut than in male; forewing bearing a reddish area on cells Cu1 and Cu2; six submarginal white dots (often circled with black, especially Cu1), from cells R4 to Cu1 (one each). Hindwing always with white dots in cells Rs and Cu1, but sometimes only one dot or none in Cu2.

**Types.** **Holotype.** ♂: Zingara, Municipio de Cali, Departamento del Valle del Cauca, Colombia, 2000 m, 03°32'23"N, 76°36'16"W, laboratory reared from first instar larva, adult emergence date 16 October 1999, genitalic dissection No. 8, M. D. Heredia; in the collection of the Museo de Entomología Universidad del Valle (MEUV).

**Paratypes.** All from Colombia: 1 ♀, same locality as holotype, adult emergence date 13 October 1999, M. D. Heredia; 1 ♂, same locality, wild-caught 24 February 2002, M. D. Heredia; 1 ♀, same locality, adult emergence date 8 December 1999, M. D. Heredia [MEUV]; 1 ♂, same locality, wild-caught 22 September 2002, M. D. Heredia; 1 ♀, same locality, adult emergence date 18 October 1999, M. D. Heredia; 1 ♀, same locality, adult emergence date 26 December 1999, M. D. Heredia; 1 ♂, Vereda El Otoño, Municipio de Cali, 1800 m, Wild-caught, 25 January 1998, M. D. Heredia [MDH]; 1 ♂, Western Cordillera, Alto de Las Cruces, 2200 m, 10 October 1998, A. H. Fassl, JB [BMNH]; 1 ♂, Kustencordillera, Cali, 1000 m, 16 July 1967, Denhez [ZSBS]; 1 ♂, Km 18, Municipio de Cali, 1800 m, June 1985, L. M. Constantino [CFC]; 2 ♂, Risaralda, Mistrató, San Antonio de Chami, W de Alto Pisones-Gaguadas, 1500 m, 17 April 1983, G. Andrade (GAC 4511, 4613); 1 ♂, Risaralda, Pereira, La Florida, La Suiza, Parque de Ucumari, 2300m, 28 June 1994, G. Andrade C. (GAC-6024, ICNL-11905); 1 ♂, Risaralda, Mistrató-Alt. Pisones, 1450m, camino a Río Currumai, 31 May 1992, G. Andrade C. (ICNL-8925); 1 ♂, same data, 1850m (ICNL-14047); 1 ♀, same data, 1300 m, 1 June 1992 (ICNL-8959); 1 ♂, Quindío, Filandia, Vda. El Roble, Finca La Popa, Casa Bremen, CRQ Int. del bosque, 2000 m, 20–22 June 1999, Diego Tobar (DIEG-1475, ICN-MHN-L-17172); 1 ♂, same data, 5–7 June 1999 (DIEG-1084, ICN-MHN-L-17183); 1 ♂, Quindío, Circasia, Vda. La Concha, Finca Membrillal, 2000 m, Int. del bosque, 21–23 April 1999, Diego Tobar (DIEG-513); 1 ♀, same data, borde del bosque, 23–25 July 1999 (ICN-MHN-L-17194); 1 ♂, same data, Vda. Membrillal, El Silencio, 8–10 June 1999 (DIEG 1160, ICN-MHN-L-17180), 1 ♂, Nariño, Ricaurte, La Planada, 1700 m, June 1999, F. G. Stiles (ICNL-11532); 1 ♂, Caldas, Samaná, Florencia, El Estadero, 1850 m, 15 June 1994, J. V. Rueda (ICNL-14038); 1 ♂, same data, 1950 m (17-NCP, ICNL 4154) [ICN].

**Additional material examined** (not included in type series): 1 ♂, Bogota, (Child), (genit. prep. ALV218-96), Rothschild Bequest, Brit. Mus. 39-1 [probably mislabelled] [BMNH]; 1 ♂, Prov. Cundinamarca, Monterredondo, 1420 m, 4 October 1956, J. Forster [ZSBS].

**Life cycle.** **Eggs** (Fig. 3a). Two eggs collected in the field measured 1.3 mm wide and 1.2 mm tall. Infertile eggs ( $n = 28$ ) laid under laboratory conditions averaged 1.3 mm wide ( $SD = 0.02$ ) and 1.2 mm tall ( $SD = 0.04$ ). Solitary, rounded, creamy white, laid on new sprouts of *Chusquea* sp., whose leaves have not yet developed to full size. Usually on underside of leaves near the base, either close to the border or near the central vein. Micropile and surrounding area flat with numerous minute cells. Under 40× magnification a series of superficial sinuous meridians (formed by two lateral lines separated by a series of tiny cells) are alternated by a narrow area of small cells. The black epicranium of the larva is visible through the chorion two days before hatching. The two eggs collected hatched on 12 October 1999 and 24 March 2000, respectively. Although we still do not know the length of egg maturation, it can be estimated to last around ten days, as extrapolated from our experience with other species of *Pedaliodes* from the area, whose females were induced to lay eggs in the laboratory.

Table 1 presents the morphometrics of the larval stages of *P. zingara*.

**First instar** (Figs. 3b, 5a, b). Duration: 8 days ( $n = 2$ ). Larval length 4.0 mm immediately after hatching. Larvae ate the chorion completely upon emergence. Epicranium: wider than body, bright black, with two prominent, apical, round scoli on vertex; epicranial cuticle with soft superficial reticulation both laterally and behind, except for scoli and area between them; epicranial setae greyish, sparse; the longest (0.3 mm) on scoli area; some lateral setae with tuberculate base. Body: creamy white, with lateral rows of very short, fine, subdorsal setae; another row of shorter and sparser setae on suprspiracular region (only visible at 40×, at least); longer and thicker, greyish setae on epicranium, prothorax and A10; those on subspiracular region translucent, long and thin, all visible at 10×.



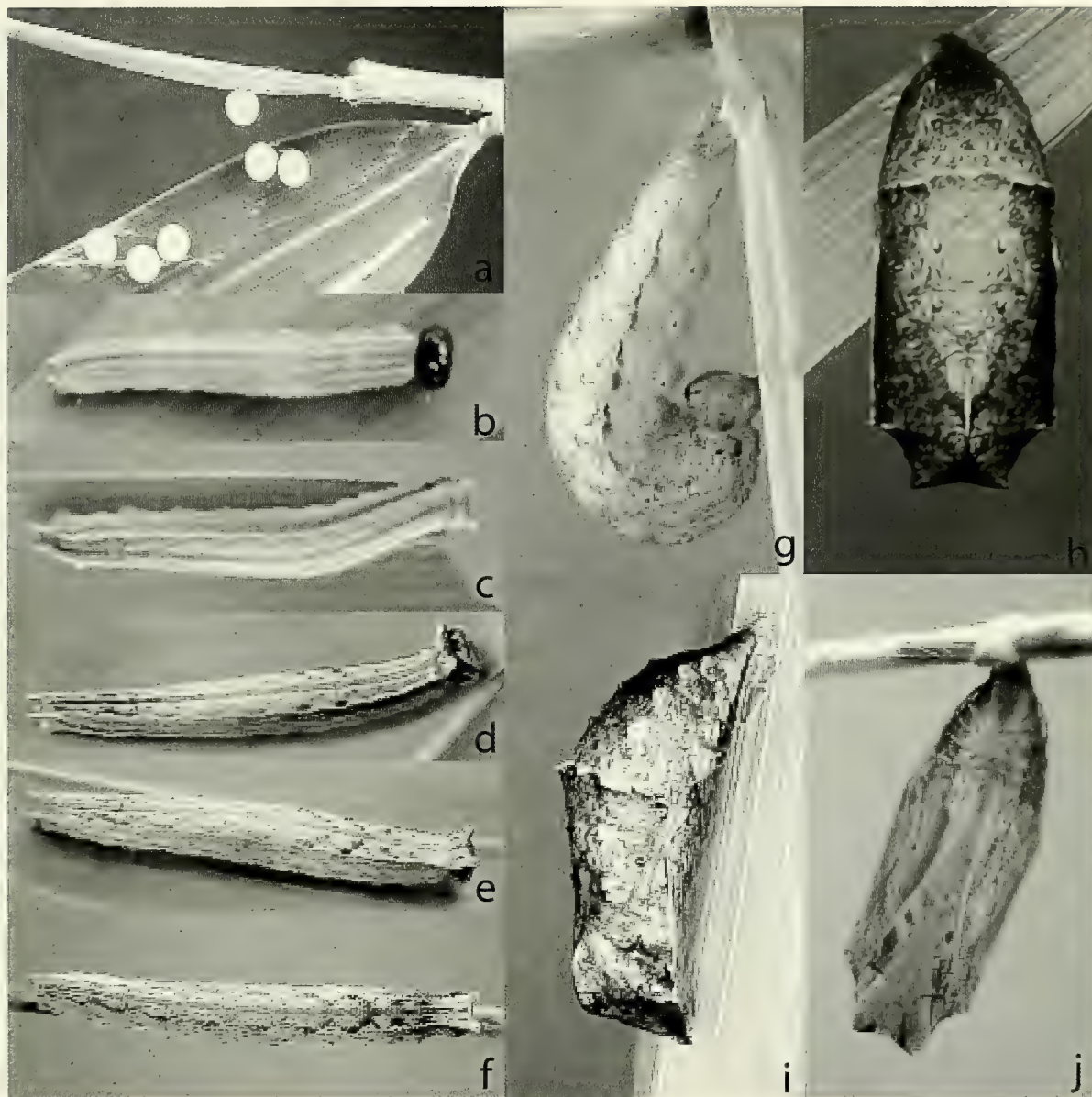


FIG. 3. Immature stages of *Pedalioides zingara*, new species; **a**, Eggs; **b**, First instar; **c**, Second instar; **d**, Third instar; **e**, Fourth instar; **f**, Fifth instar; **g**, Prepupa lateral view; **h**, Pupa dorsal view; **i**, Pupa lateral view; **j**, Pupa ventral view (images are not proportional. Actual sizes in Table 1).

Upon development, larvae turn creamy-greenish with two creamy-white lines parallel to dorsal medium line, and two more lateral subdorsal lines running to segment A3; area between two central lines, and area above subdorsal lines turn light brown from A3 towards bifurcation of suranal plate. Legs and prolegs creamy-white.

**Second instar** (Figs. 3c, 5c). Duration: 7.8 days ( $n = 6$ ;  $SD = 1.47$ ). Exuviae totally consumed by larvae after molting. Larval length: 7.2 mm ( $n = 5$ ;  $SD = 0.56$ ). Epicranium with two scoli on vertex, brown, lighter behind scoli; dotted all over cuticle, tiny rounded concavities all over cuticle except for frontoclypeus, small region parallel to it, area between ommatidia, and mandibular region; concavities lightly darker than background; scoli covered by secondary setae with notably tuberculate bases; same kind of setae also occur sparsely laterally on posterior part of epicranium. Body: dorsal medium line brown, bordered with creamy-white lines, more

visible on thorax and somewhat deviated on A5, disappearing beyond that; creamy-white subdorsal line on each side; brown between these and the medium one, turning lighter and variegated with brown to A6, and from extremity of A6 to dark brown bifurcation; dark brown band underneath subdorsal line, laterally and ventrally light greenish. Under great magnification ( $40\times$ ) all body covered by tiny, light greenish chalazae, with secondary setae; spiracles light brown, connected along by a tenuous creamy-greenish line; ventral border ending in a creamy-white line.

**Third instar** (Figs. 3d, 5d). Duration: 7.5 days ( $n = 6$ ;  $SD = 1.2$ ). Larval length: 10.3 mm ( $n = 6$ ;  $SD = 0.77$ ). Epicranium: wider than body, with two scoli on vertex, brown tones alternate with dark brown producing a characteristic design (see Fig. 3d); dots and concavities pattern similar to previous instar; area without concavities creamy-white, only with light dots; two spots adjacent to superior





FIG. 4. Androconial patches on forewing dorsal of the holotype of *Pedaliodes zingara*.

vertex of frontoclypeus, in frontal area; w-design in front of frontal portion of scoli, and lateral regions of epicranium dark brown; posterior portion of scoli area creamy-white, light brown between scoli. General aspect of body, light brown dorsally, creamy-greenish ventrally; at great magnification (40 $\times$ +) entirely covered with chazae of creamy-white color at base, and secondary, very short, light brown setae; a reddish-brown medium band, darkened from caudal extremity of segment A6 to segment A10; a creamy-white band running between central and subdorsal regions, including a light brown band from thorax to A1; the latter diffusing as dark brown dots, especially prominent at extremity of A1 and on A2; becoming a dark band again from caudal portion of A6 towards A10; another dark brown band on supraspiracular region, narrowing progressively towards last segments; spiracles brown; supraspiracular line creamy-white.

**Fourth instar** (Figs. 3e, 5e). Duration: 8.7 days ( $n = 6$ ;  $SD = 1.4$ ). Larval length: 15.9 mm ( $n = 6$ ;  $SD = 1.57$ ). Epicranium: slightly wider than body, with two scoli on vertex, same color pattern as previous instar; scoli with rounded surface, lacking prominent tuberculate bases; secondary setae more dense, longer around ommatidial and mandibular regions. Body color and design basically similar to those of third instar, but creamy-white subdorsal lines become caudally undulated; dark brown  $\sim$ -shaped marks between these and medium dorsal brown line on segments A1 and A2, vanishing behind A2; some thoracic dark dots parallel to median line; a dark brown band laterally on thorax, underneath creamy-white line, vanishing at caudal extremity of body; spiracles brown; subspiracular line creamy-white.

**Fifth instar** (Figs. 3f, 5f). Duration: 14.2 days ( $n = 6$ ;  $SD = 1.6$ ). Larval length: 24.2 mm ( $n = 6$ ;  $SD = 2.43$ ). Epicranium: about same width as body, with two scoli on vertex, cuticle darker, but same pattern as fourth instar; frontoclypeus and mouthparts darkened; oral region almost black. Posterior portion of head (including backside of scoli) and prothorax, all creamy-white, lighter than rest of body, which is beige and sparsely marbled with greenish-brown. Body: dark greenish design on T2, T3, A1, and A2; a pair of dark green lines running along medium line of dorsum, more distinct on thorax; lateral narrow lines of creamy-white on subdorsal region of thorax,

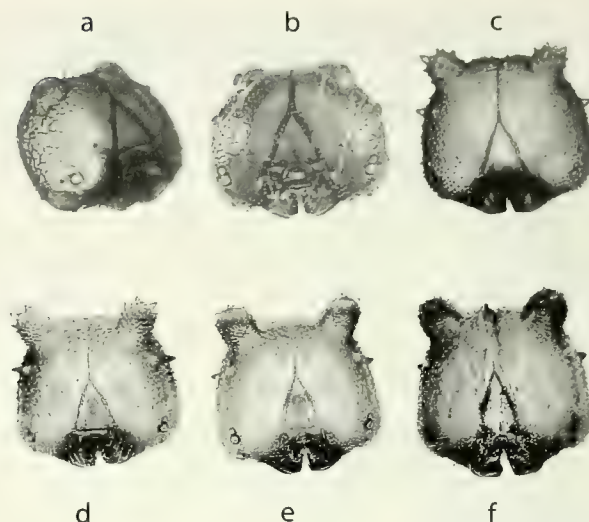


FIG. 5. Head capsule of *Pedaliodes zingara*: a, First instar lateral; b, The same frontal; c, Second instar frontal; d, Third instar frontal; e, Fourth instar frontal; f, Fifth instar frontal.

which becomes wavy and discontinuous in posterior segments thus conferring a dorsal design of rhomboidal, continuous figures, darker on A1, A2, and from extremity of A5 to A7; as a result of dense distribution of minute chazae with diverse colors at their bases, and secondary short setae, body appears entirely marbled with greenish-brown and creamy-white; thorax laterally dark green; spiracles dark brown; subspiracular line creamy-white. Body ventrally sprinkled with brown; ventral border dark brown. Legs creamy-white, claws dark; prolegs creamy-white with a lateral dark brown spot.

**Additional observations.** Some individuals appear darker than others or with a sharper design on thorax and/or on both rhomboidal markings and marbling. While at rest, the larva brings down the epicranium to the substrate bending the body at segment T2. At the end of this instar almost all larvae pupated while fixing the cremaster to the underside of *Chusquea* leaves. We were unable to locate pupae in the field, probably due to their highly cryptic appearance when attached to dark stems, which might be their natural substrate as observed in other *Pedaliodes* species (unpubl.). Prepupa stage (Fig. 3g) lasted three days for all individuals we studied; the larvae then lost their ordinary color pattern and became entirely beige. Average length of prepupae was 38.5 mm.

**Pupa** (Figs. 3h-j). Duration: 22.5 days ( $n = 6$ ;  $SD = 2.9$ ). Length: 17.6 mm ( $n = 6$ ;  $SD = 0.53$ ); width: 6.9 mm ( $n = 6$ ;  $SD = 0.27$ ). In dorsal view the general aspect of the pupa is that of a small lantern, having a more or less cylindrical shape from T1 to A3, and a conical one from A10 to the shelf projected at A3, which ends in a dentate edge. Background color brown with profuse darker dotting and markings; cephalic portion ends in two angles separated 3.3 mm from each other ( $n = 6$ ,  $SD = 0.2$ ); basal area of wings also ends in two angles separated 6.4 mm from each other ( $n = 6$ ;  $SD = 0.22$ ); rows of minute protuberances (resembling pin heads) on both sides of medium line, from A1 to A6, being reddish-brown on A4, A5, A6 and marked with black on A1, and A2; dorsally darkened by grayish marbling in central area between two rows of protuberances; broadened portion between segments A4 and A5 where cuticle is thinner and smooth; margin of cornice at A3, inner margin of wing, and a triangle formed between epicranium and margin of keel at T2, all darker brown, bright reddish-brown in some individuals. Ventrally wing region with brown patches, slightly darker in costal region, with some sparse dots on external margin of wing. Mesothoracic legs with two brown patches, the first one longer, entering the prothoracic legs. Antenna carved with light brown dots. Laterally, two grayish bands from cremaster to wing outer margin, running behind spira-



TABLE 1. Morphometrics of larval stages of *Pedaliodes zingara*, new species. All measurements in millimeters, standard deviation in parenthesis.

	1st instar	2nd instar	3rd instar	4th instar	5th instar
Epicranium	n = 6	n = 5	n = 6	n = 6	n = 5
Width	0.99 (0.03)	1.34 (0.04)	1.83 (0.05)	2.63 (0.10)	3.76 (0.11)
Height	0.87 (0.05)	1.20 (0.03)	1.67 (0.07)	2.42 (0.09)	3.44 (0.16)
Scoli	n = 6	n = 5	n = 6	n = 6	n = 5
Inner separation	0.29 (0.01)	0.45 (0.05)	0.55 (0.03)	0.85 (0.04)	1.31 (0.08)
Width	0.22 (0.02)	0.30 (0.00)	0.41 (0.02)	0.60 (0.05)	0.90 (0.12)
Height	0.10 (0.00)	0.29 (0.02)	0.48 (0.02)	0.61 (0.04)	0.88 (0.02)
Suranal plate	—	n = 3	n = 4	n = 4	n = 2
Bifurcation length	—	0.25 (0.05)	0.55 (0.12)	0.78 (0.14)	1.00 (0.00)
Tip separation	—	0.51 (0.02)	0.80 (0.08)	1.26 (0.09)	1.80 (0.00)

cles; the latter bordered with dark brown. Cremaster as long as wide, hooks brown, and silk light brown; pad always appearing as a brown patch.

Development time. At 20°–24° the development of *Pedaliodes zingara* from egg hatching to imago emergence has taken 68.7 days on average. Considering that the egg might last around ten days (as speculated above) the entire life cycle of the species should complete in nearly 79 days.

**Etymology.** In naming this species after Finca Zingara, a farm property of the Gensini family, we recognize the relevance of that area for recent studies on biodiversity and conservation of Colombian cloud forests. *Zingara* is also one of the Spanish words for Gypsy.

**Remarks.** In natural conditions *Pedaliodes zingara* lays solitary eggs on the underside of fresh leaves of one or two possibly undescribed species of *Chusquea* (L. Clark, pers. com.). This habit has already been recorded for several species of the genus, and also in other pronophiline butterflies (DeVries 1987).

One adult female of *P. zingara* bred entirely in the laboratory started ovipositing on *Chusquea* leaves eight days after emergence, laying a total of 64 infertile eggs (minimum 2, maximum 24 eggs/day). This individual was also dissected after its death. We found 40 chorionated eggs plus 80 developing eggs, half of the latter were in advanced vitelogenic stage. Thus, it yielded a reproductive potential of 184 oocytes. During the dissection it was noted that the fat body surrounding the ovarioles was scarce.

More than half of the fertile eggs of all *Pedaliodes* species found in the field were parasitized.

## DISCUSSION

**Early stage biology.** *Pedaliodes* is one of the most diverse genera of butterflies (270+ spp., according to Vilorio 2002). However, it is remarkable that to date only parts of the life cycles of three species are known: *Pedaliodes phoenissa* (Hewitson) in Colombia (Schultze 1930), *P. cremera* Godman & Salvin; (DeVries 1987) and *P. dejecta* (Bates) (DeVries 1987). Other early stage records for '*Pedaliodes*' species refer to taxa lately transferred to other genera (Forster 1964,

Adams 1986). Müller (1886) wrote a very detailed description of the fifth instar and the pupa of *Praepedaliodes phanias* (Hewitson) from Brazil, DeVries (1987) identified the foodplant and provided the description of the egg of *Praepronophila perperna* (Hewitson) in Costa Rica, and Pelz (1997) described the full life cycle of *Parapedaliodes parepa* (Hewitson) bred from Ecuadorian eggs on a supplementary European host.

The eggs of *P. zingara* are similar to those described by Schultze (1930) for *P. phoenissa* and those of *Parapedaliodes parepa* (Pelz 1997). They all show "fine and regular reticulation." Studies with higher magnification might reveal unique structures for each taxon (see Sourakov 1996).

Females of *P. zingara*, like those of *P. manis*, *P. poesia*, and *P. peucestas* (MDH unpubl.) emerge with eggs undeveloped, vitelogenic, and, mostly, previtelogenic.

From observation and dissection of infertile females fed at the laboratory and of fertile, fresh females brought from the field, we have a first idea of the pattern of production of eggs in these species. Their age-fecundity graphs (MDH unpubl.) recall pattern 'C' illustrated by Boggs (1997: Fig. 1). The potential of these species is about 200 eggs, and during peak fertility the daily production fluctuated around 20 eggs. Under lab conditions these species last 4–8 days before they mature and start ovipositing. Other Satyrinae grown under similar conditions never matured their eggs, possibly because, besides food, they need to be stimulated by copulation (Ehrlich & Ehrlich 1978, MDH unpubl.).

*Pedaliodes zingara* feeds on at least two species of *Chusquea* (sections *Chusquea* and *Longiprophyllae*, respectively) that occur in the study area, which suggests that in this case there is no strict host specificity, a common feature observed in butterfly larvae that feed on Poaceae (Singer & Ehrlich 1991, Sourakov 1996, Pelz 1997).

During daytime satyrine larvae are generally cryptic in behavior and appearance; for instance, first instar



individuals of *P. zingara* remained mainly resting beneath the apex of the bamboo leaves, moving only when they started to eat at the leaf edges. From second instar onwards, they spent most of the time over the brown or brownish stems, preferably feeding on the leaf bases. Thus, the aspect and position of the larvae is cryptic, assuring protection against potential visually-hunting predators. Other possible defense mechanisms in these insects are unknown. All *Pedaliodes* larvae we know have a ventral, prothoracic, neck gland of creamy-white color, but they did not release any detectable odor or substance during manipulation and handling.

Most of the morphological features of the head and body cuticle of *P. zingara* larvae are superficially shared by *P. phoenissa* and *P. parepa*. If there were better descriptions of the coloration and reticulation design of the epicranium of these species, then significant differences between them could be established (Sourakov 1996, and pers. obs.). Each species shows a unique pattern of larval coloration, particularly on the fifth instar. The shape of the pupa of *P. zingara* is not unlike that of *Parapedaliodes parepa*. Schultze (1930) does not provide enough details of this stage to compare with *P. zingara*, but in our experience the pupae of different *Pedaliodes* species may differ much in shape and coloration from each other.

The duration of the life cycle of *P. zingara* was shorter than that of *P. phoenissa* and *P. parepa*. Major differences were observed in the fifth instar of *P. parepa* (30 days) and the pupa stage of *P. phoenissa* (37 days). This is possibly due to the fact that the last two species live naturally in colder zones (altitudes between 2500 and 3000 m), as it is generally accepted that higher temperature results in faster development of larvae (Knapp & Casey 1986).

**Systematic relationships.** Most of the major works on the genus *Pedaliodes* (Thieme 1905, Forster 1964, d'Abrera 1988) and other studies dealing with Colombian taxa (Bayern 1902, Fassl 1910, 1911, 1915, 1918, Krüger 1924, Adams 1986, Pyrcz 1999, Pyrcz & Viloria 1999), either did not consider this taxon or misidentified it as *P. phrasiclea* (see synonymy above).

Comparing wing shape and color pattern, androconial systems, male genitalic structure, and geographical distributions, we conclude that *Pedaliodes zingara* is another member of the '*pisonia*-group' (see discussion in Viloria & Pyrcz 2000: 39–40, and Viloria et al. 2001), a possibly monophyletic cluster of 'lowland' species within the genus. It is morphologically intermediate between the Venezuelan *P. pisonia* and *P. phrasiclea*, which apparently ranges from southern Colombia to Bolivia.

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# LARVAL MORPHOLOGY AND BEHAVIOR OF *ANTIRRHEA WEYMERI* SALAZAR, CONSTANTINO & LÓPEZ, 1998 (NYMPHALIDAE: MORPHINAE) IN COLOMBIA

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**ABSTRACT.** The immature stages of *Antirrhea weymeri* Salazar, Constantino & López, 1998 are described from the eastern slopes of the Cordillera Occidental (2000 m), Departamento del Valle del Cauca, Colombia. At emergence, females have around 100 oocytes, eight of which are mature eggs and another 16 are ready to receive the chorion. They lay their eggs in groups of 5–8 on the under surface of the pinnae of *Prestoea acuminata* (Arecaceae). The larvae are gregarious, and their behavior appears to be very close to that of *Morpho sulkowskyi* Kollar as far as the use of cervical and grooming glands is concerned. These new observations provide further support to a close phylogenetic relationship between *Morpho* and *Antirrhea*, as proposed by DeVries et al. (1985) and DeVries (1987).

**RESUMEN.** Se describen los estados inmaduros de *Antirrhea weymeri* en la vertiente oriental de la Cordillera Occidental (2000 m), Departamento del Valle del Cauca, Colombia. Las hembras recién emergidas tienen cerca de 100 oocitos, de los cuales ocho son maduros y 16 más están listos para recibir el corion. Ponen sus huevos en grupos de 5–8 en el envés de las pinnas de *Prestoea acuminata* (Arecaceae). Las larvas son gregarias y exhiben un comportamiento muy similar a las de *Morpho sulkowskyi* Kollar en relación con el empleo de las glándulas cervical y de acicalamiento. Estas nuevas observaciones corroboran la estrecha relación filogenética entre *Morpho* y *Antirrhea*, propuesta por DeVries et al. (1985) y DeVries (1987).

**Additional key words:** fecundity, glands, life cycle, *Prestoea acuminata*, pupal dimorphism.

*Antirrhea weymeri* Salazar, Constantino & López, 1998, is a local and infrequent morphinae of the Cordillera Occidental of Colombia between 1600 and 2200 m (Salazar et al. 1998, pers. obs.). Active at dusk, it remains motionless during the day and is only detected when, being disturbed, it abandons its resting place to fly low through the forest until it finds a new perch. We have always observed it in areas bordering a stream, either perched low on a shrub or on rotting trunks on the forest floor. *Antirrhea weymeri* is illustrated in D'Abrera (1984:368) as *Antirrhea* sp. nov. (Salazar et al. 1988; Fig. 1), and it may be related to *A. geryon* Felder & Felder of the Cordillera Central and *A. phasiana* Butler, the three taxa perhaps being conspecific (Lamas cited in Salazar et al. 1998).

Of the 21 *Antirrhea* species mentioned by D'Abrera (1984), only the life cycle of *A. philoctetes* (Linnaeus) has been published (Urich & Emmel 1990), and then without any information on the behavior of the larva. Müller (1866) describes the egg and the first instar of *A. archaea* Hübner and notes the resemblance between this and the corresponding instar of *Morpho achillides* Felder & Felder. DeVries et al. (1985) examined the cladistic relationships between the genera *Antirrhea*, *Caerois*, and *Morpho* using larval characters of *A. pterocopa* Salvin & Godman, *A. multiades* (Fabricius), *Antirrhea* sp. nov., and *A. philoctetes*. We here contribute the first descriptions of clutch size, morphology and behavior of the immature stages, pupal dimorphism, hosts, and potential fertility of *Antirrhea weymeri*, and corroborate the close phylogenetic

relationship between *Morpho* and *Antirrhea* proposed in DeVries et al. (1985) and DeVries (1987).

## MATERIALS AND METHODS

The study area (1900–2200 m, 3°32'23"N, 76°36'16"W) is 4 km north of "El Dieciocho" (km 18 of the Cali-Buenaventura highway) on the road to Pavas, on the eastern slope of the Cordillera Occidental, municipality of Cali, Departamento del Valle del Cauca. Ecologically, the zone is "lower montane moist forest" of Holdridge's Life Zones system (Espinal & Montenegro 1963). The vegetation consists of patches of more or less degraded cloud forest within suburban estates devoted to recreation or low-intensity forestry and livestock raising.

On 19 August 2001, in a patch of secondary forest bordering the Aguacalara creek we discovered five *Antirrhea weymeri* larvae clustered near the middle of the abaxial surface of one of the pinnae of a young palm (*Prestoea acuminata* [Willd.] H. E. Moore), with leaves approximately 2 m long. Six species of Arecaceae have been recorded in the study area (J. Giraldo pers. com.), and juvenile hosts of *A. weymeri* had the physiognomic characteristics of *Prestoea acuminata*. It was possible to confirm the host identification by comparing the young plant with *A. weymeri* larvae with a nearby adult in fruit. This palm species inhabits Andean pre-montane and montane forests from Colombia to Bolivia, and lower altitudes in Central America and the Antilles (Henderson et al. 1995).

The larvae were transferred to the laboratory in Cali



TABLE 1. Morphometric characteristics of *Antirrhea weymeri*, in millimeters, standard deviation in parentheses.

	3rd Instar	4th Instar	5th Instar
HEAD CAPSULE	n = 5	n = 4	n = 3
width	2.63 (0.027)	3.76 (0.62)	5.55 (0.49)
height	3.06 (0.054)	4.46 (0.047)	5.66 (0.28)
SCOLI			
width	0.23 (0.027)	0.31 (0.025)	0.47 (0.03)
height	0.26 (0.022)	0.27 (0.028)	0.3 (0)
separation at the base	0.16 (0.021)	0.26 (0.025)	not measured

to follow their life cycle. Larvae and pupae were kept in glass jars at a controlled temperature not above 24°C with a 12L:12D photoperiod. Larval food (*P. acuminata*) was changed daily and maintained fresh in moist paper under refrigeration, or replaced with fresh field collected material.

The early stages were described and measured in vivo using a stereomicroscope (15–20×) equipped with 0.1 and 0.05 mm precision grids (Table 1, Fig. 4). The epicrania, a fourth instar larva, some pupal exuviae, and the adults are at present deposited in the private collection of MDH.

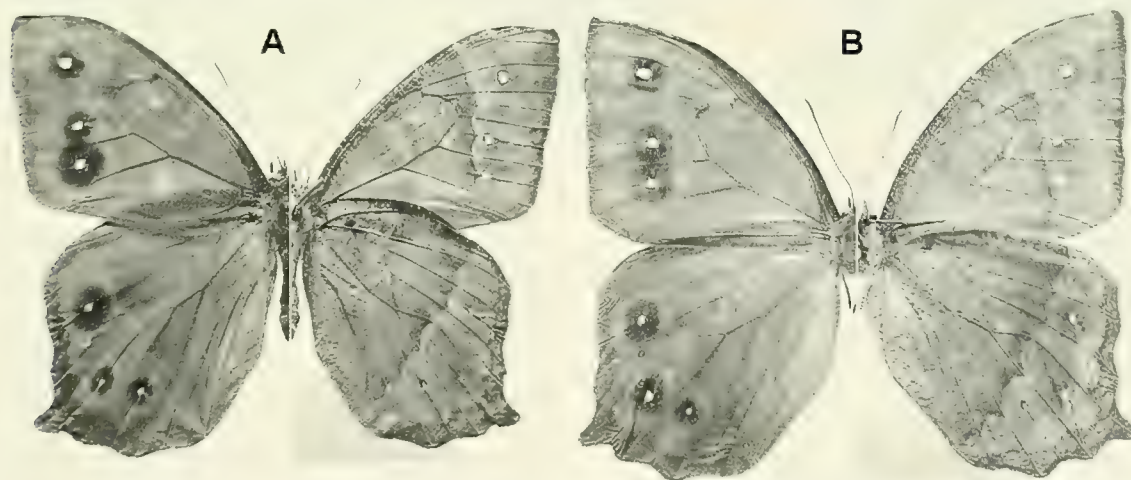
## RESULTS

**Egg.** (Fig. 2A) We found the remains of clutches on the abaxial surface of pinnae of young palms, but not on adult palms that were carefully surveyed with binoculars. Eggs were white, hemispherical, laid in small clusters of 5–8 (mean = 5.8, SD = 1.30, n = 5), in most cases in contact with each other, and positioned towards the middle of the leaf. Three eggs with hardly any of their opercular dome consumed measured 1.75 mm in diameter and 1.20 mm in height. Eggs were positively identified by comparison with mature eggs obtained by dissecting newly emerged females in the laboratory.

**Third instar.** The larvae were at the end of this instar at the time of collection. **Head:** (Table 1, Fig. 4) triangular, with two very close scoli at the vertex, terminating in three forward-pointing setae, one anterior and two posterior. Anterior seta dark brown, and longest and largest in diameter. One posterior seta is dark and intermediate

in diameter and length, the other light brown, thinner and shorter. Epicranium cream-colored with a dark brown patch extending transversally between stemma IV longitudinally to the first third of the epicranial suture; its shape is trapezoidal and leaves the interior of the frontal triangle with no coloring. Laterally, there is a dark brown semicircular patch that runs in line with stemma V to the posterior edge of the epicranium. There are small dark brown marks between the first four stemmata and stemma VI at the beginning of another posterior-pointing patch. The edges of the mandibles and the base of the clypeus are dark brown. Cutting edge of the mandibles is uniformly curved, and the mandible wrist is papillate. Cuticle of the epicranium presents tiny circular pits over its entire surface, including the scoli, but excluding areas of the frontoclypeus, adfrontal, and regions close to stemmata and mandibles. The entire cuticle is uniformly spotted with tiny pinacula from which arise fine golden setae; in areas near the mouth and stemmata these setae are longer and supported on minute chalazae. Laterally, there are prominent chalazae from which arise thick, forward-pointing, dark brown setae of different sizes; viewed in profile, most are slightly curved; the shorter occur singly along the edge of the lateral brown-colored patch and extend to the end of the frontal trapezoidal coloration. Some short setae are scattered among the long setae. Several long lateral setae are flat, in the form of small ribbons narrowing towards the ends. On the vertex there are only thick setae of the scoli and one seta anterior to these on a chalaza. Stemmata are all approximately equal in diameter; stemma VI is slightly posterior to V. **Body:** segments with annulets: A1 has three rings, one anterior (cephalic) broader, and two posterior narrower but equal in size; from A2 to A7 there is one broad anterior and four narrow posterior rings equal in size; A8 to A9 lack defined rings. A broad black dorsal band with a yellow subdorsal band on each side and a pattern of dorsal Vs distributed from thorax to A6 with vertices at midline. The yellow lateral band touches a narrow black band that is followed by a light green lateral area and a supraspiracular cream line. Ventrally light green with a dark ring around the T1 leg. Suranal plate bifurcate with two long, white-spotted, black prolongations covered with numerous scattered secondary setae. Laterally, the larva presents a great quantity of long, white, downward-pointing secondary setae; dorsally one only sees a few, scattered long and white setae. The duration of this instar not observed; duration of the pre-molt was one day.

**Fourth instar** (Fig. 2B) Newly molted length 21.90 mm (SD = 0.90, n = 5) not including the suranal plate; suranal plate 11.36 mm (SD = 0.26, n = 5). **Head:** approximately the same width as the body, with the same setal pattern and coloring as previous instar (Table 1), but now frontally beneath the scoli there are several long, thick, dark brown setae, and a greater density of thin golden setae

FIG. 1. *Antirrhea weymeri*. A, Male; left, dorsal view; right, ventral view. B, Female; idem.



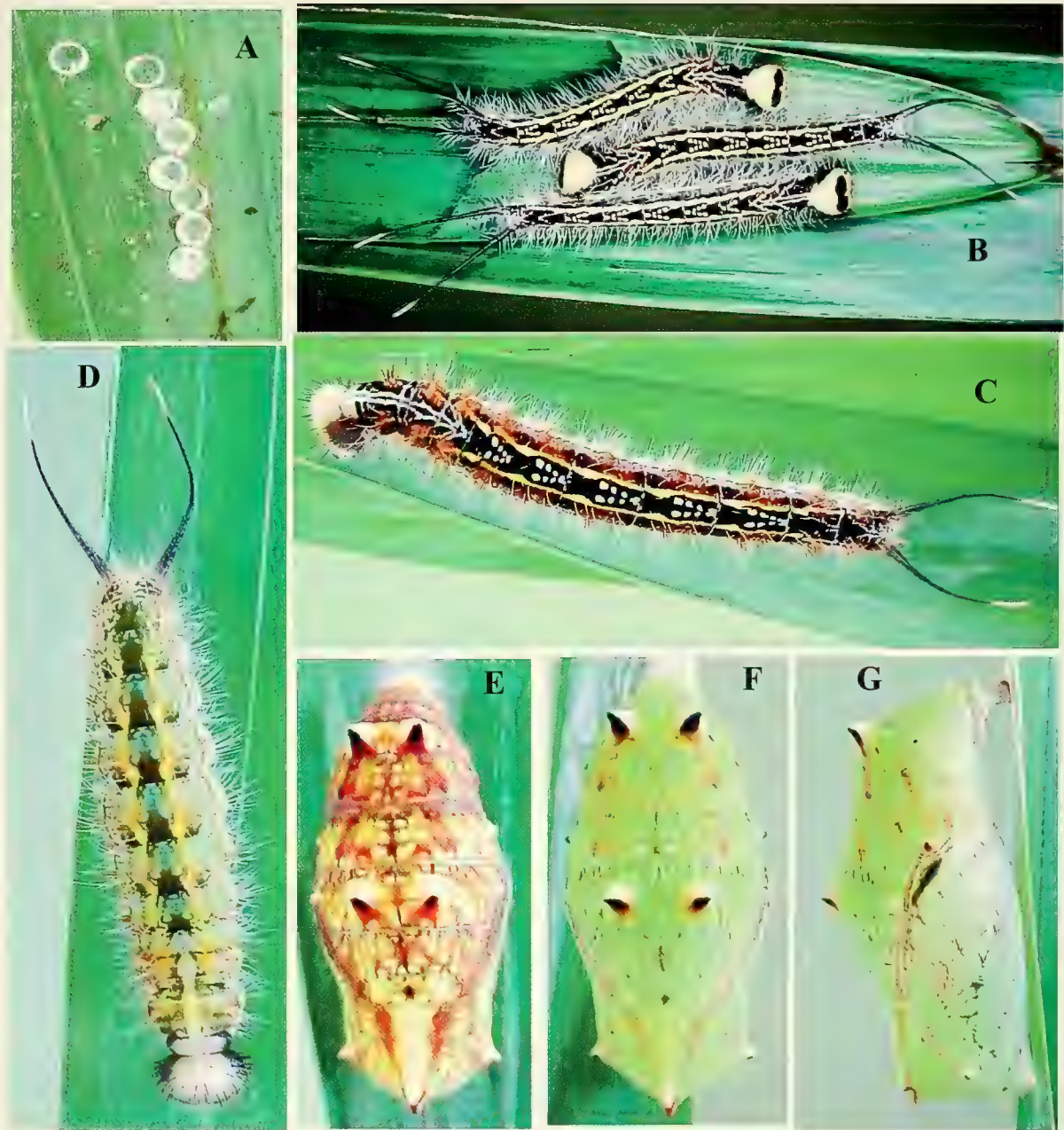


FIG. 2. Immature stages of *A. weymeri*. **A**, Remains of clutch in *Prestoea acuminata*. **B**, Fourth instar. **C**, Fifth instar. **D**, Prepupa. **E**, Dark pupa, dorsal. **F**, Light pupa, dorsal. **G**, Light pupa, lateral.

over entire frontal surface. **Body:** (under 10× magnification) many long, whitish, downward-pointing setae are seen, distributed mainly over the subspiracular region, but there are also scattered long (1.5–2.0 mm), whitish secondary setae over the entire body. There also appear small clusters of shorter (0.8 mm) brown setae mixed with the white on the T2–T3 subdorsal region (setae in this region are forward-pointing as in *Morpho* on verrucae), and from A1 onwards these setae are shifted slightly towards the supraspiracular region; on A3–A4 very sparse, and on A5–A9 they again are dispersed and more numerous; all these setae appear barbed under 40× magnification. Suranal plate with two long, white-spotted, black prolongations covered with numerous, dispersed black secondary setae; those at basal end are white and longer (1.20 mm) except for those

on apex which are white and very short. Body with a dorsal black band edged with a thin golden yellow strip running from end of T3 to the beginning of A7 on subdorsal region. This strip is slightly broader at the anterior edge of each segment. Some reddish brown marks anterior to the yellow strip of T3 and the broad ring of A1. Two parallel white lines run along the center of the black dorsal fringe from T1 to middle of first ring of segment A1, at which point they pass around two small fissures, one on each side of midline (see Fig. 3B). These fissures are in the same position as the tufts on segment A1 in *Morpho sulikowskyi* Kollar and other species of *Morpho*, and suggest they might have the same glandular function. At these fissures there begins a series of white spots, one on each side of each ring, forming a V pattern with vertex at midline, continuing to A6, at



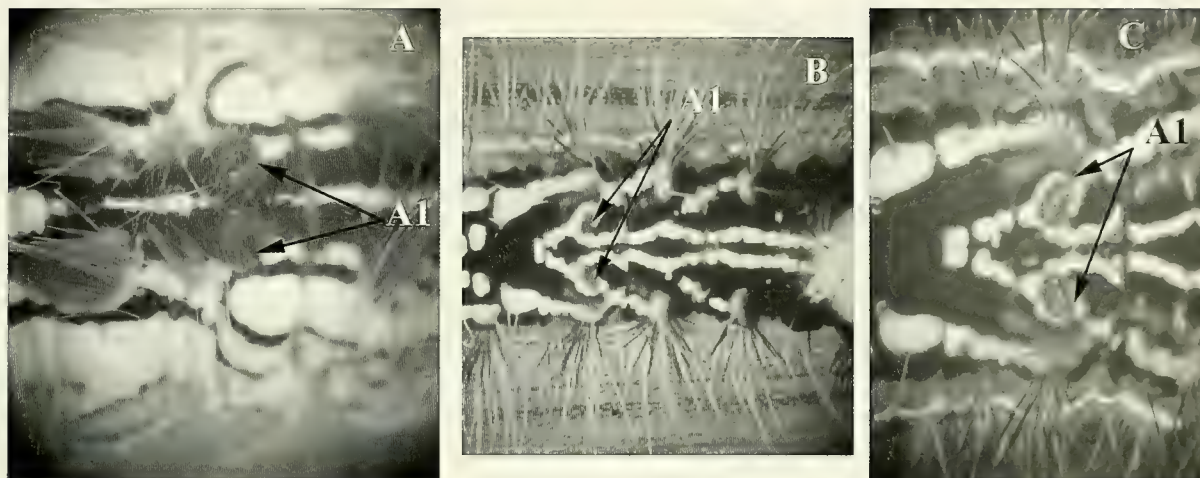


FIG. 3. **A**, *Morpho sulkowskyi*, two drops of secretion on A1. **B**, *Antirrhoea weymeri*, two fissures on A1. **C**, Larva of *A. weymeri* on molt to fifth instar showing swollen fissures.

A7 it becomes a thin line parallel to the end of the segment. At A8 and A9, there are scattered dorsal pale cream patches. The lateral yellow band touches a black band with brown highlights, and ventrally there is a transparent green band, then a supraspiracular white line. Spiracles brown. Ventral region transparent green; around the front legs a burgundy-colored ring embracing the light green prothoracic gland region. The mean duration 10.75 days ( $SD = 0.5$ ,  $n = 4$ ). One larva died. The pre-molting period, two days.

**Fifth instar** (Fig. 2C) Newly molted length 29.9 mm ( $SD = 0.14$ ,  $n = 4$ ) not including the mean length of the suranal plate (11.5 mm,  $SD = 0.40$ ). **Head:** (Table 1) same setal pattern and coloring as previous instar, but now scoli are thicker while maintaining the same length. **Body:** coloring basically the same as previous instar, but larva now has a chocolate brown tint. Yellow band has brown inclusions along its length, as does the blackish band following it; greenish lateral band now brown, more intense on edges that touch the cream line. There are also clusters of short brown setae on all segments (except A10) distributed transversally from subdorsal lines to supraspiracular region. Within each segment from A1 to A7, the setae form two parallel rows; A8 to A9 have only a single row. When in two rows the anterior is denser in brown setae and occurs after the broadest ring in each segment. The densest short brown tufts correspond to segments T2–T3, A1, and A8. Dorsally and laterally, above the supraspiracular region there are widely-spaced, long, thin white setae that are most abundant on subspiracular region, and point downwards. Ventrally identical to previous instar. **Prepupa** begins when brown coloration disappears between subdorsal and supraspiracular area which then becomes greenish; subsequently, the entire surface becomes greenish with only the central black area between the pattern of Vs that have expanded while still being bordered by the yellowish band (Fig. 2D). Mean prepupa duration 2.5 days ( $SD = 0.57$ ,  $n = 4$ ) and the complete fifth instar 21 days ( $SD = 2.44$ ,  $n = 4$ ). Larvae disperse towards the end of this instar, and pupate alone.

**Pupa.** (Figs. 2 E–G) Mean length 19.55 mm ( $SD = 0.26$ ,  $n = 4$ ), width 8.92 mm ( $SD = 0.41$ ). The broadest segment measured laterally coincides with beginning of A3. There were two coloring types: three of the pupae were an intense light green (almost phosphorescent) and one had a yellowish background color strongly marked with brown. Dorsally, the texture of the pupa is granular, with pyramidal protuberances on each side of midline on A3 and A6. Upper part of protuberance is yellowish cream, the lower brown with a black patch. There is a slightly smaller lateral protuberance at the base of the wing, another two connected to form an M on the keel of T2, and finally two much smaller ones beside spiracle A4, and the other on the spiracle A3. A brown stripe corresponding to part of the

outer edge and the inner edge of the wing extends to the keel. Spiracles brown. On both A4 and A5 a slanted brown stripe extend each side toward the midline. A prominent dilatation between A4 and A5 that allows lateral movements of the pupa when it is disturbed. Background green color is marked with small stripes or minute dots of light brown. A9 has a dorsal ledge of tiny protuberances. Cremaster with tiny protuberances on each side of base, but ventrally they are less perceptible. Cremaster slightly longer than wide, fluted dorsally and ventrally; hooks brown; silk white. Ventrally two minute brown-apexed protuberances on epicranium separated by 2.5 mm. Small dark brown patch in the proboscis area. Wing discal cell and veins with diffuse light brown markings. Submarginal area with small brown stripes and tornus with a dark, nearly black, elongated patch. Background yellowish green color lighter ventrally.

In light-colored pupae there were individuals with the brown band along the outer and inner edges of the wing to the keel of T2 very dark, and with wings having a great profusion of ventral spots and stripes. Dorsally, the **brown pupa** was chocolate brown from the cremaster to A5 except for light upper part of the A6 protuberances. The dilatation between A4 and A5 also brown, with slanted brown bands on A5–A4. In these segments the background color is somewhat more yellowish than other segments, but with a greater concentration of brown marks (spots and stripes) on the background color. The band around the inner margin of wing to the keel is dark brown and broad. Ventrally greenish cream with a pattern of small stripes, spots and patches darker brown than in the light-colored pupa. Mean duration of pupa, 16 days ( $n = 4$ ,  $SD = 0.86$ ).

**Larval behavior.** Larvae always consumed the molt, and occasionally the tips of the suranal plate. When handled some expelled an oral drop of greenish liquid. As in *Morpho*, larvae had a prothoracic gland and the same associated behavioral repertoire: they push the head back, lift the legs, and move the head from side to side, at times emitting a scent from the cream-colored prothoracic gland, and occasionally they also lifted the suranal plate and pushed it forwards, lifting the prolegs on the last segment. The scent of the prothoracic gland is not as intense as in some *Morpho*. We observed that larvae were more sensitive to any disturbance immediately following molt.



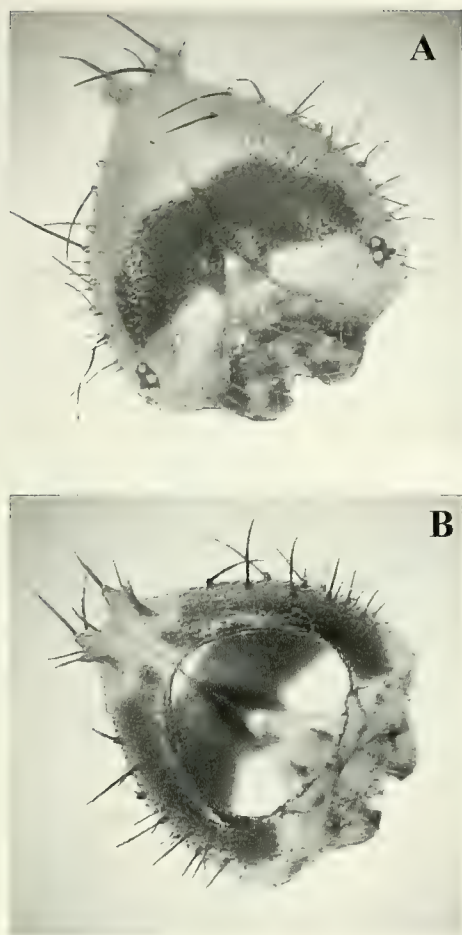


FIG. 4. Head capsule of *A. weymeri*, third instar. **A**, Dorsal view. **B**, Ventral view.

Using 40 $\times$  magnification we observed three larvae during the pre-molt period slightly extrude the fissures of A1 leaving a smooth swollen light green surface (Fig. 3C). In one larva observed with stereomicroscope while molting, a small drop of a transparent secretion was seen on the rounded surface of the fissures, much like those of the A1 tufts in *M. sulkowskyi* (Heredia & Alvarez-López in press, Fig. 3A). *A. weymeri* larvae also have the same grooming behaviour as described by DeVries and Martinez (1993) for *Morpho* larvae.

A newly molted larva pushed its head back and moved T2 and T3 setae over segment A1. It then turned its head towards the last segments, running first down one side and then the other. The larva performed this sequence even if there was apparently no drop of secretion available to anoint the lateral setae, i.e., all newly molted larvae behaved in the same way, with or without secretion.

**Reproductive potential.** Two females (wing

lengths 34.3 mm and 38.4 mm) were dissected the day following emergence. Both had a great amount of fat body. At the base of each ovariole, the first egg was chorionated and ready to ovulate into the oviductus lateralis. The following two eggs in both females were vitellogenic, large in size, and about to receive the chorion. In one female there were 11 eggs in formation per ovariole, plus eight chorionated, for a total of 96 potential eggs. In the other, there were 12 eggs in formation per ovariole plus eight chorionated (total 104 eggs). The infertile chorionated eggs ranged in size between 1.65 and 1.70 mm in width, and 1.15 mm in height. They were hemispherical and smooth textured.

#### DISCUSSION

Adults of *A. weymeri* have a behavior similar to that described for other *Antirrhea* species (DeVries 1987, DeVries in D'Abrera 1984, Ulrich & Emmel 1990, Salazar et al. 1998, and pers. obs.), and also use *Areaceae* host plants. *A. weymeri* shares morphological aspects of eggs, larvae, and pupae with the other *Antirrhea* species for which something is known (DeVries 1987, Ulrich & Emmel 1990), and the main differences appear to be in clutch size and color patterns of larvae and pupae.

The larvae of *Antirrhea weymeri* are gregarious and have prothoracic and grooming glands like those described for *M. cypris* Westwood (DeVries & Martinez 1993) and *M. sulkowskyi* (Heredia & Alvarez-López in press). When disturbed, larvae of *A. weymeri* extrude their prothoracic gland and emit a scent, but this response is more rapid immediately following molt. However, in our experience with *M. sulkowskyi* the prothoracic gland scent is produced at all times with the same rapidity.

The secretion of the grooming gland was first described by DeVries and Martinez (1993) for *Morpho cypris* as "a drop of clear liquid from a dorsal pore located between the subdorsal tufts on A1." In *M. sulkowskyi* (Heredia & Alvarez-López in press) the secretion appears as two independent drops, one for each A1 tuft, implying the existence of two pores (Fig. 3A). Likewise, *A. weymeri* has two small fissures on each side of the midline (Fig. 3B, C) in the same position as the A1 tufts of *M. sulkowskyi*. However, histological studies are needed to confirm the glandular nature of these structures and to compare them with the corresponding structures of *Morpho*. This paper represents the first observations on the behavior and glands of *Antirrhea* larvae (C. Penz pers. com.), and lends support to the phylogenetic placement of *Antirrhea* within the Morphinae (DeVries et al. 1985).



The larval regurgitation, gregarious behavior, and glands with their associated behavioral repertoire may have a defensive function against predators or parasitoids (DeVries & Martinez 1993, Gross 1993, Fitzgerald 1993, Heredia & Alvarez-López in press), but we have no observations on such interactions. In our study area *Antirrhea weymeri* is rare with an erratic presence; indeed, a search for over 10 months yielded no more larvae, despite checking many *Prestoea acuminata* individuals.

Color dimorphism of pupae has been explained as the result of genotype-environment interaction, where production of a green or a brown pupa depends on environmental signals received by the prepupa, and on its genetic capacity to respond (Hazel & West 1979, Sims & Shapiro 1983). In natural conditions *Antirrhea weymeri* very possibly pupates not only on palm leaves, but on many substrates, and this may favor pupal dimorphism and crypsis (West & Hazel 1982).

Nothing is known about the egg production patterns in butterflies that feed on juices from rotting fruit, tree exudates, fungi, or animal droppings. This group, to which *Antirrhea weymeri* belongs, in many places in the tropics may represent 50 % of the butterfly fauna (DeVries 1988, DeVries & Walla 2001, and pers. obs.). From the dissections of two females, we conclude that females could begin to lay eggs soon after copulation since they are born with a group of chorionated eggs and another one of advanced vitellogenic eggs. They would not depend on feeding immediately, nor on copulation for their eggs to begin maturing (Ehrlich et al. 1978). Instead, the availability of food resources for the female could be important subsequently for the remaining eggs to mature (Boggs 1997). This preliminary information is necessary to begin to understand the reproductive strategies of such species as *A. weymeri*, many of which have small populations and very particular environmental requirements making them highly vulnerable to habitat destruction.

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## TWO NEW SPECIES OF *BAILEYA* GROTE (NOLIDAE: RISOBINAE) FROM THE SOUTHEASTERN UNITED STATES

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**ABSTRACT.** Records for seven species of the genus *Baileya* Grote in Louisiana are discussed. All five described North American species are known for the state, though only one, *Baileya ophthalmica* (Guenée) was previously recorded. Two new species are described: *Baileya acadiana*, new species and *Baileya ellessyoo*, new species. A key to *Baileya* species and images of adults for all seven species are provided.

**Additional key words:** Louisiana, Mississippi, Sarrothripinae, Texas, voltinism.

The genus *Baileya* is a member of the Nolidae subfamily Risobinae. Kitching and Rawlins (1999) removed the subfamilies Nolinae and Sarrothripinae from the Noctuidae and placed them in the family Nolidae, recognizing that these two subfamilies are more closely related to the Arctiidae than to the Noctuidae, and as a result combined them as the reinstated family Nolidae and placed it next to the Arctiidae. Following this action, I treat the genus *Baileya* as belonging to the family Nolidae while recognizing that prior literature has *Baileya* placed in the Noctuidae.

Forbes (1954), Hodges (1983), and Covell (1984) list five species of *Baileya* Grote as occurring in North America north of Mexico, but no records were specifically mentioned for Louisiana. In the most recent list of Noctuidae for Louisiana, Chapin and Callahan (1967) include only one species, *Baileya ophthalmica* (Guenée). The purpose of this paper is to review the status of the genus *Baileya* in Louisiana, and provide descriptions for two new species.

To date, seven species have been collected in Louisiana using mercury vapor/ultraviolet light traps. Two of these are new, and are described below. Among the other five species, *Baileya doubledayi* (Guenée) has been taken March through August in Natchitoches and St. Tammany Parishes, representing at least three broods. *Baileya ophthalmica* (Guenée) has been taken March through August in Ascension, Bossier, Calcasieu, East Baton Rouge, St. Tammany, Tangipahoa, Vernon, and West Feliciana Parishes, representing at least three broods. *Baileya dormitans* (Guenée) has been taken March, June, and August in West Feliciana Parish, representing at least three broods. *Baileya levitans* (Smith) has been taken March, April, and May in Bossier, St. John the Baptist, and West Feliciana Parishes, representing one brood. *Baileya australis* (Grote) has been taken March through November in West Feliciana Parish, representing at least four broods. Forbes (1954) and Covell (1984) reported three broods for *australis*.

### *Baileya acadiana* Brou, new species

(Figs. 1a, b, 2)

**Male. Head:** Color gray to dark gray, frontal tuft rounded; palpi color similar gray; antennae similar gray, simple, slender, and acuminate. **Thorax:** Entire dorsal color similar to head, appearing light gray or dark gray, due to light refraction from shiny scales; frontal area scales form raised collar on dried specimens; scales of tegula elevated well above mesothorax; ventral color gray, including legs. **Abdomen:** Dorsal color as described for thorax; ventral color light gray. **Forewing:** Dorsal ground color shiny gray, black basal line demarcates basal area, of which frontal portion is light gray, caudally light brown; area distal to basal line dark gray approaching a narrow, often obscure line of light gray scales proximally bordering antemedial line, becoming more obscure or nonexistent caudally; area between antemedial and medial lines shiny gray; medial line usually evident near costal margin, occasionally obscure, but more often indistinguishable caudally; distinct median area of shiny white scales, most prominent between medial and postmedial lines and extending beyond postmedial line as small triangular area intersecting costal edge, and at inner margin as a minute spot or short transverse line; postmedial line poorly defined mesially; front-distal edge of white area defined by short, black, transverse bar obliquely intersecting costal edge, caudal half of bar forms acute or right angle as it abruptly changes direction towards outer margin, forming a v-shape; three short longitudinal apical dashes acutely approach, but do not intersect distal edge of frontal portion of v-shaped bar; pseudo anal dashes usually tiny or obscure, sometimes forming black zigzag near inner margin; subterminal line obscure or indistinguishable, represented midway by two or three minute groupings of black scales, distally bordered by similar minute groupings of whitish scales; light dusting of shiny whitish scales over frontal half of wing between postmedial line and outer margin, including fringe of most specimens; terminal line represented by series of sometimes less contrasting gray to darker gray, well-defined, crescent-shaped spots between veins; caudal portion of fringe uncontrastingly shiny gray; ventral ground color shiny gray, appearing very light gray or very dark gray, depending upon angle viewed; same light refraction effects responsible for presence or absence of well marked dark vein lines over entire surface depending on angle viewed; light gray scales along entire inner margin and continuing along outer margin as antimarginal shade band to dark apical spot; crescent-shaped apical patch at outer margin, either well marked with whitish scales or obscure with gray scales; small crescent-shaped patch of whitish scales proximal to dark apical spot along costal margin to dark postmedial spot; on some specimens a black costal spot or short bar evident at center of crescent-shaped whitish patch; on some specimens to varying degrees, second rectangular-shaped patch of whitish scales along costal edge between dark postmedial and midcostal spots, viewed from different angles, both white patches can appear



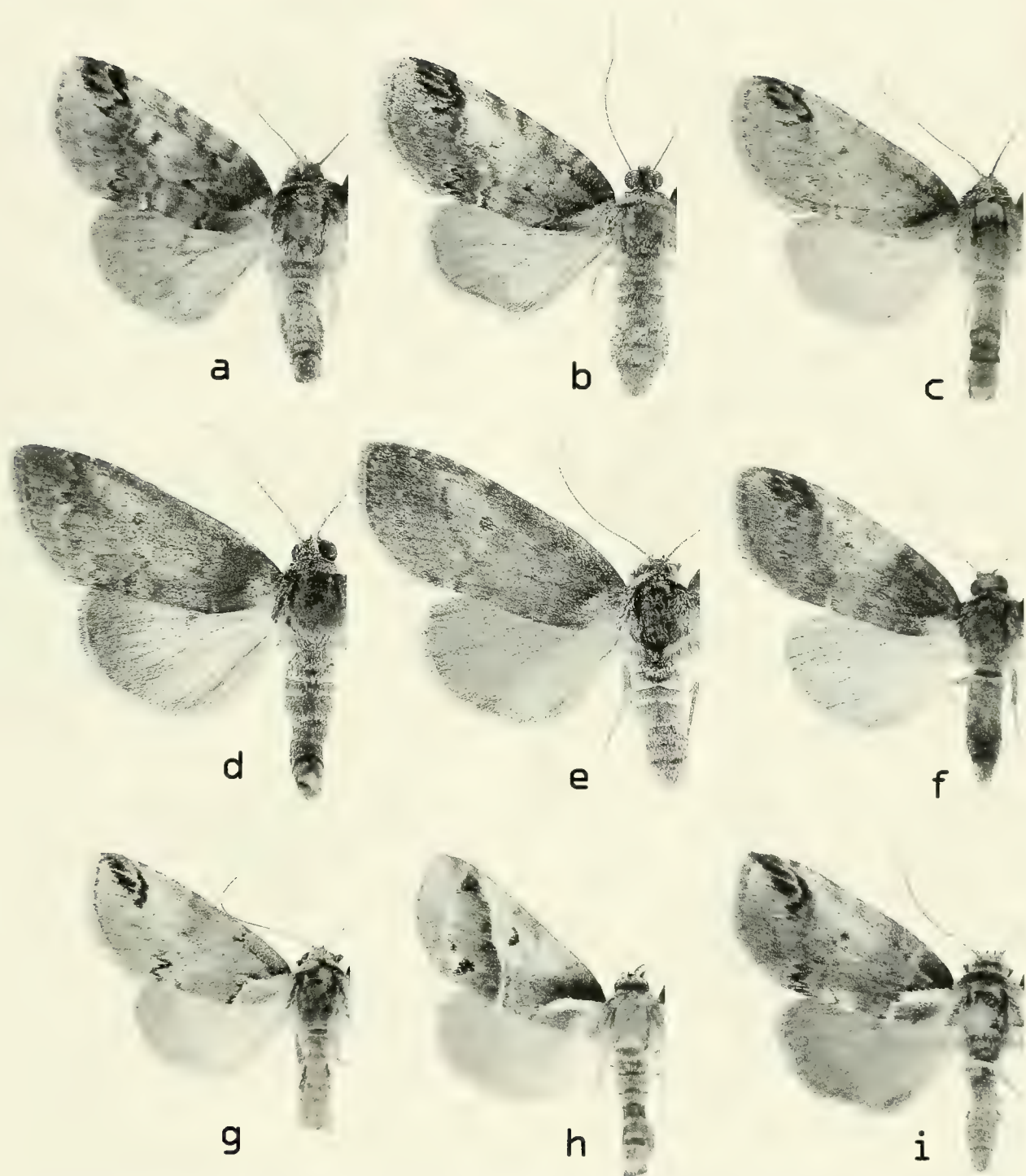


FIG. 1. *Baileya* species. **a**, *B. acadiana* Type male; **b**, *B. acadiana* Allotype female; **c**, *B. dormitans* male; **d**, *B. ellessyoo* Type male; **e**, *B. ellessyoo* Allotype female; **f**, *B. levitans* male; **g**, *B. australis* male; **h**, *B. doubledayi* male; **i**, *B. ophthalmica* male.

bordered by fully encompassing crescent-shaped dark borders, rather than just dark spots at ends; terminal line and fringe as described for dorsal surface; length  $\bar{x}$  = 12.2 mm (11.0–13.2;  $n$  = 32).

**Hindwing:** Dorsal color uniform shiny light to dark gray, fringe contrastingly lighter gray, ventral ground color light or dark gray; crescent-shaped dark gray discal spot; proximal of postmedial line, light

gray, except near base and along costal margin, dark gray; distal of postmedial line usually dark gray without markings, or light gray antimarginal shade band proximally along outer margin; narrow outer marginal band or line of whitish scales, increasing in width apically as a whitish patch bounded distally by dark gray terminal line, band, or distal edge of dark gray area; fine white line along entire costal



edge. **Genitalia:** ( $n = 8$ ) (Fig. 2) Valves bilaterally symmetric, ventral margins often slightly more convex than dorsal margins, homogeneous, broad bases, apically obtuse; oblong spatulate distal lobes, dorsal margins slightly more convex; basal portion of right process of sacculus stout, distal portion arcuate, ensiform, acuminate. **Female. Head, Thorax, and Abdomen:** As described for male. **Forewing:** Dorsal and ventral colors as described for male, except white scales often more pronounced and numerous; length  $\bar{x} = 13.3$  mm (12.5–13.9;  $n = 22$ ). **Hindwing:** Dorsal and ventral colors as described for male. **Genitalia:** ( $n = 5$ ) (Fig. 2) Appendix bursa nearly half the size of the corpus bursa, a single signum in the form of an elongated rasp-like band on side surface of corpus bursa.

**Types. Holotype** ♂ (Fig. 1a), USA, Louisiana, St. Tammany Parish, 4.2 miles (6.8 km) NE Abita Springs, sec.24, T6S, R12E, 5 June 1989. **Allotype** ♀ (Fig. 1b), same locality, 20 April 1992. **Paratypes: Alabama,** 2 ♂ and 2 ♀, DeKalb and Monroe Counties, 4 April to 19 May 1990–95, **Arkansas,** Arkansas County, 1 ♀ 20 Aug 1970, Madison County, Blue Springs State Park, 2 ♂ and 3 ♀ 27–31 May 1966–71, Washington County, 2 ♂ 30 May 1979, **Louisiana,** 597 ♂ and 404 ♀, Ascension, Bossier, Iberville, Natchitoches, St. John the Baptist, St. Tammany, Tangipahoa, and West Feliciana Parishes, 20 February–22 October 1961–2003; **Mississippi,** 114 ♂ and 130 ♀, Adams, Amite, Forest, Franklin, George, Grenada, Hancock, Harrison, Hinds, Holmes, Issaquena, Lafayette, Lauderdale, Lowndes, Madison, Oktibbeha, Pearl River, Pike, Lee, Rankin, Smith, Tishomingo, Warren and Winston Counties, February–December 1959–2001, **Texas,** San Jacinto County, 1 ♀ 12 May 1985. Holotype, allotype, and paratypes deposited in Florida State Collection of Arthropods, Gainesville. Additional paratypes deposited in Canadian National Collection of Insects and Arachnids, Ontario; Louisiana State Arthropod Museum, Baton Rouge; Mississippi Entomological Museum; and the private collections of E. Metzler, R. Kergosien, E. C. Knudson, and the author. Primary types are designated with the words Holotype and Allotype on white labels outlined with red color, secondary types designated with the word Paratype on white labels outlined with blue color.

**Distribution.** *Baileya acadiana* has been confirmed from the states of Alabama, Arkansas, Louisiana, Mississippi, and Texas. In Louisiana it is the most commonly encountered species of *Baileya*.

**Flight period.** In Louisiana, *Baileya acadiana* has three annual broods, first brood peaking around April 8, subsequent broods peaking at 60-day intervals (Fig. 3).

**Etymology.** The epithet is derived from the colloquial term for the region as well as the endemic human populations, early settlers in the southern rural regions of Louisiana, the Acadians (Cajuns), French settlers who traveled to Louisiana from (Acadia) Nova Scotia. *Baileya acadiana* is the only common *Baileya* species known to occur in these southern areas of the state.

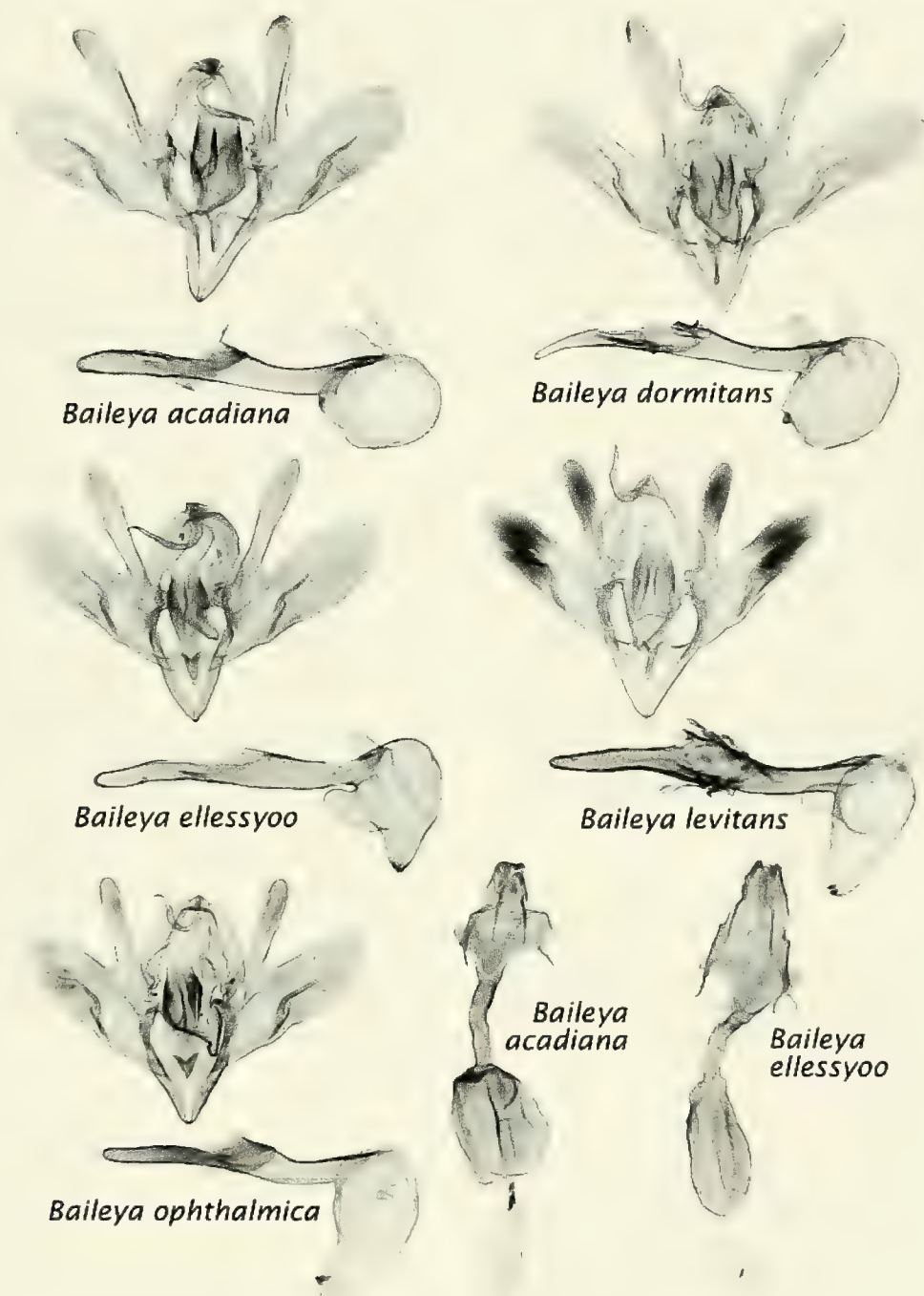
**Diagnosis.** *Baileya acadiana* appears to be most closely related to *B. dormitans* on the basis of vesica characteristics, though the spatulate lobes of *acadiana* are shorter in length and less curved than in *dormitans*. *B. acadiana* and *dormitans* also share a distinct black forewing basal line, though *dormitans* lacks the distinct forewing median area of whitish scales found on *acadiana*.

## *Baileya ellessyoo* Brou, new species (Figs. 1d, e, 2)

**Male.** Head: Color gray, frontal tuft rounded; palpi color similar or contrastingly lighter gray. **Antennae:** Simple, similar gray color. **Thorax:** Dorsal color similar to head, appearing gray or very dark gray, due to light refraction from shiny scales; scales on frontal area form a raised collar on dried specimens; scales of tegula elevated well above mesothorax; ventral color gray or light gray, including legs. **Abdomen:** Dorsal color same as described for thorax; ventral color light gray. **Forewing:** Dorsal ground color monochrome lead gray, entirely overlaid with medium intensity sheen; basal line obscure or nonexistent, small amount of whitish or light gray scales at base, on some barely evident; area distal to basal line lead gray approaching obscure antemedial line, which on some is indiscernible; fine, delicate line of shiny whitish scales proximally bordering antemedial line extending from costal to inner margins; area between antemedial and medial lines uniformly blanketed with same delicate, light dusting of shiny whitish scales; median line obscure, more often indiscernible; reniform spot nearly indistinguishable to distinct tiny, nearly black dot, on some, few white scales in center appearing as minute eyespot; blanket of shiny whitish scales distal of gray median line, to gray, often obscure or sometimes indistinguishable postmedial line; postmedial line distally bordered by fine obscure line of shiny whitish scales, sometimes barely evident; this fine whitish line bordered by dark gray, sometimes broad and diffuse line, extending from costal to inner margins where it meets the ends of crescent-shaped obscure zigzag subterminal line; subterminal line dark gray, distally bordered by irregular, often unconnected groupings of white scales; area between subterminal line and outer margin lead gray, more often with obscure dusting of whitish scales; delicate and thin terminal line occurring as a series of contrasting dark gray spots between veins; fringe uncontrastingly gray; ventral ground color shiny light gray or dark gray, depending upon angle viewed; light gray scales along entire inner margin, and continuing along outer margin as obscure antemarginal shade band intersecting costal margin subterminally; maculation limited to faintly dark reniform spot and obscure subterminal line; this line sometimes evident simply as a shade change proximal to antemarginal shade band, small crescent-shaped subterminal patch of whitish scales along costal margin; on some specimens, a dark costal spot at center of crescent-shaped patch, and sparse whitish scales evident medially along costal margin; terminal line and fringe as described for dorsal surface; length  $\bar{x} = 15.1$  mm (14.3–16.3;  $n = 28$ ). **Hindwing:** Dorsal color uniformly gray, shiny or dull depending upon angle viewed; on some specimens color becomes lighter gray basally; terminal line often represented only by distinct change from gray to lighter gray fringe color; fringe longitudinally bisected by bold dark line; ventral ground color very light gray to whitish, generously peppered with varying amounts of dark gray scales. **Genitalia:** ( $n = 8$ ) (Fig. 2) Valves bilaterally symmetric, homogeneous, broad bases, dorsal margins markedly convex, ventral margins gently curving approaching nearly obtuse apex; elongated, spatulate, distal lobes, dorsal margins markedly convex; distal portion of right process of sacculus curvilinear, acuminate. **Female. Head, Thorax, and Abdomen:** as described for male. **Forewing:** Dorsal and ventral colors as described for male, except white scales occasionally more pronounced and numerous; length  $\bar{x} = 15.2$  mm (13.9–16.7;  $n = 20$ ). **Hindwing:** Dorsal and ventral colors as described for male. **Genitalia:** ( $n = 5$ ) (Fig. 2) Appendix bursa one-fourth of the size of the somewhat elongated corpus bursa, single signum in the form of a rasp-like elongated band on surface of the corpus bursa.

**Types. holotype** ♂ (Fig. 1d), USA, Louisiana, Natchitoches Parish, Kisatchie National Forest, near Gorum, 10 March 1986. **allotype** ♀ (Fig. 1e), same locality and date. **paratypes: Alabama,** Barbour



FIG. 2. Genitalia of *Bailey* species.

County, Blue Springs St. Pk. 1 ♀ 17 April 1976, Monroe County, 2 ♀ (4–5) April 1995, **Florida**, Liberty County, Torreya State Park, 2 ♂ and 1 ♀ March 1979–95, **Georgia**, Gilmer County, 1 ♂ 9 April 1992, Gordon County, 1 ♂ and 2 ♀ 13–19 2001–02, Morgan County, Hard Labor Cr. S. P. 7 ♂ and 3 ♀ 18 April 1988, Whitfield County, 18 March 1995, **Louisiana**, same locality as type, 10 ♂ and 1 ♀, March and April 1986, **Mississippi**, Tishomingo, Lee, and Winston Counties, 115 ♂ and 42 ♀, March–May, 1986–99, **Missouri**, Barry County, 1 ♀ 16 April 1967, Franklin County, 1 ♂ 9 April 1976, **Texas**, Polk County, Big Sandy

Creek Unit, 1 ♀ 8 April 1995, Sabine County, Sixmile, 2 ♂ 13–14 March, 1989, San Jacinto County, Double Lake Rec. Area, Coldspring, 3 ♀ 15 March 1990. Holotype, allotype, and paratypes deposited in Florida State Collection of Arthropods, Gainesville. Additional paratypes deposited in Canadian National Collection of Insects and Arachnids, Ontario; Florida State Collection of Arthropods; Louisiana State Arthropod Museum Baton Rouge; Mississippi Entomological Museum; and the private collections of E. Metzler, R. Kergosien, E. C. Knudson, and the author. Primary types are designated with the words Holotype and



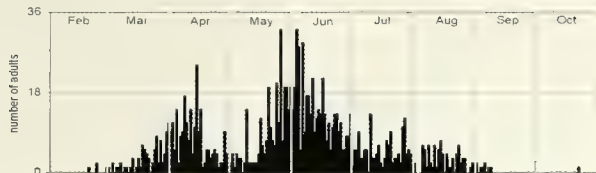


FIG. 3. *Baileya acadiana* adults captured at sec. 24, T6S, R12E, 4.2 mi. NE Abita Springs, Louisiana,  $n = 1200$

Allotype on white labels outlined with red color, secondary types designated with word Paratype on white labels outlined with blue color.

**Distribution.** *Baileya ellessyoo* has been confirmed from the states of Alabama, Florida, Georgia, Louisiana, Mississippi, Missouri, North Carolina, and Texas.

**Flight Period.** In Louisiana, *Baileya ellessyoo* has a single annual spring brood peaking in March and April.

**Etymology.** The epithet is a rhyme of the acronym for Louisiana State University (LSU).

**Diagnosis.** *Baileya ellessyoo* appears to be most closely related to *B. levitans* on the basis of vesica characteristics, though it differs from *B. levitans* in lacking a black ring around the reniform spot and in having a more even forewing ground color, without white medial shading and without a dark line proximal to the subterminal line characteristic of *levitans*. The two species also differ in male genitalia with *ellessyoo* exhibiting a broader valvae with longer and less curved spatulate lobes than that of *levitans*.

#### DISCUSSION

Three species of *Baileya* have a conspicuous white forewing basal patch: *B. australis*, *B. doubledayi*, and *B. ophthalmica* (Fig. 1g–i). The two new species, *B. dormitans* (Fig. 1c), and *B. levitans* (Fig. 1f) all lack the prominent white forewing basal patch. *Baileya*

*acadiana* is the most widespread and commonly encountered member of the genus in Louisiana and Mississippi, and its wing pattern is most similar to *B. dormitans* and *B. levitans*. Males of *B. acadiana* may sometimes be confused with males of *B. dormitans*, while some females of *B. acadiana* appear similar to females of both *B. dormitans* and *B. levitans*. Similarly, *B. ellessyoo* is nearest in appearance to *B. levitans*. *Baileya ellessyoo* is the largest in size and most inconspicuously marked of known *Baileya* species.

The right valvae of all five previously described *Baileya* species were illustrated by Forbes (1954). All male species of *Baileya* exhibit a short to long bilaterally symmetrical distal lobe extending from the base at the dorsal edge of each valvae. A comparison of the male genitalia of *B. dormitans*, *B. levitans*, *B. acadiana*, and *B. ellessyoo* from Louisiana indicates that each species is separable (Fig. 2), with the valves, distal lobes, and saccular processes differing significantly in size and shape among these four species. In Louisiana, the genitalia of male *B. dormitans* (Fig. 2) exhibit a long, lanceolate right valvae, end tapering somewhat symmetrically to a blunt point; process of sacculus barely sinuous and acuminate; elongated, spatulate distal lobes; all characteristics illustrated in Forbes (1954). In Louisiana, the genitalia of male *B. levitans* (Fig. 2) exhibit a short asymmetrical right valvae, the ventral edge arciform, gently curving to a blunt end, dorsal edge straight, curving near blunt end; process of sacculus nearly straight and acuminate; short, straight-edged, non-spatulate, obtuse, distal lobes; all characteristics illustrated in Forbes (1954). The male genitalia of *B. ophthalmica* is also illustrated here for comparison (Fig. 2).

#### KEY TO BAILEYA SPECIES

1. Basal area of forewing with white shading (occasionally white absent in some *ophthalmica*, but in these the black basal line extends down to the posterior margin of the wing) ..... **2**  
 Basal area of forewing gray: basal line if present, extending to anal vein ..... **4**
2. Forewing with postmedial line white, oblique, almost straight ..... *doubledayi*  
 Forewing with postmedial line black, usually obscure, wavy and scalloped ..... **3**
3. Forewing with black bar adjacent to costa, on inner margin of subterminal line straight; reniform spot obscure (a dark smudge) ..... *australis*  
 Black bar adjacent to costa curved, C-shaped: reniform spot distinct, a black dot surrounded by a line forming a circle ..... *ophthalmica*
4. Forewing with prominent black bar adjacent to subterminal line near costa and several black streaks near apex ..... **5**  
 Forewing without contrasting black marks towards costa or with diffuse darker shading in area ..... **6**
5. Larger species, forewing 13 to 15 mm; median area similar in color to subterminal and basal areas or slightly paler; reniform spot a dark spot ..... *dormitans*  
 Smaller species, forewing 11 to 13 mm; extensive silvery-gray shading in upper portion of median area; reniform spot distinct, a black dot surrounded by a black line forming a circle ..... *acadiana*
6. Forewing generally contrasting with pale shading in median area and darker shading adjacent to subterminal line; reniform spot distinct, a black dot surrounded by a black line forming a circle ..... *levitans*  
 Forewing an even gray color with only slightly paler shading in median area; reniform spot a darker blackish-gray dot ..... *ellessyoo*

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A NEW SPECIES OF *NANODACNA* CLARKE (LEPIDOPTERA: ELACHISTIDAE:  
AGONOXENINAE) FEEDING ON THE SEEDS OF *AUSTROCEDRUS CHILENSIS* (CUPRESSACEAE)  
IN ANDEAN ARGENTINA

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**ABSTRACT.** Characters of the adult, larva, and pupa of *Nanodacna austrocedrella* Landry & Adamski, new species, are described and illustrated. The seed-feeding larvae cause damage to Andean Cedar, *ciprés de la cordillera* [*Austrocedrus chilensis* (D. Don.) Fl. & Bout., Cupressaceae] in Chubut Province, Argentina. The species is compared to other species of *Nanodacna* and to species of *Homoeoprepes* Walsingham from the Neotropics. Criteria for its inclusion in *Nanodacna* and the phylogenetic significance of characters of immature stages for relationships within the Agonoxeninae are discussed.

**RESUMEN.** Se describen e ilustran caracteres del adulto, larva, y pupa de *Nanodacna austrocedrella* Landry & Adamski, nueva especie. Las larvas que comen las semillas causan daño al ciprés de la cordillera [*Austrocedrus chilensis* (D. Don.) Fl. & Bout., Cupressaceae] en la provincia de Chubut, Argentina. Se compara la especie con otras especies de *Nanodacna* y a las especies de *Homoeoprepes* Walsingham de la región neotropical. Criterios para ser incluido en *Nanodacna* y la significación de caracteres filogenéticos de los estadios inmaduros para relaciones entre Agonoxeninae son discutidos.

**Additional key words:** immature stages, phylogenetics, *Homoeoprepes*, Andean Cedar.

In 1995 and 1996 extensive damage was found to the fruit and seeds of *ciprés de la cordillera* (*Austrocedrus chilensis* (D. Don) Fl. & Bout., Cupressaceae) in the vicinity of Trevelin, Department of Futaleufu, Province of Chubut, Argentina. Damage was caused by larvae of a microlepidoptera that developed in the fruit and consumed the seeds. Due to the economic importance of the tree, the life history of the species, extent of the damage and infestation, and possible natural enemies had been under investigation by researchers at the Universidad Nacional de la Patagonia in Esquel (Chubut). Results of this study were published (Gomez & Klasmer 1997) but the species remained nameless. The purpose of this paper is to name and describe the species.

Two lots of specimens were sent to JFL in June 1996 with a request to provide an identification of the species, however those specimens were unmounted and in rather poor condition. The moths represented an undescribed species of *Nanodacna* Clarke.

In order to obtain a series of good-quality specimens for describing the species, arrangements were made with the Argentinian research team (through the courtesy of Drs. Cecilia Gomez and Mario Rajchenberg) to obtain live larvae and host material in an attempt to rear the moths. These efforts were successful and in this paper we present the description of the adult, larva, and pupa of this new species. We indicate how to differentiate it from other species of *Nanodacna* and briefly discuss the composition and phylogenetic position of *Nanodacna*.

#### MATERIALS AND METHODS

Several lots of live larvae with fruit and pieces of bark of *ciprés de la cordillera* were received in Ottawa from the INTA-Trevelin Forest Station, Futaleufu, Chubut, Argentina between November 1996 and April 1997. Field collecting dates are 13 November 1996, 29 November 1996, 9 December 1996, 8 February 1997, and 10 April 1997. Lots were placed in screen cages in an incubator at 20°C with 40% R.H. and a 16:8 LD regime, and misted sporadically. Most larvae collected in November and December 1996 were very young and did not survive due to subsequent fruit deterioration. However, larvae of the February and April 1997 lots were mature when received and a number of the larvae had already pupated after burrowing in the bark chips and the styrofoam packing material. The photoperiod and temperature were reduced progressively during the month of May to mimic the onset of austral autumn; lights were turned off and the temperature set at 4°C from June to August. The process was reversed beginning in late August to achieve full daylight by mid-September.

Thirty-four adults emerged over the period of about a week at the end of September and the beginning of October 1997. Adults were killed, pinned and spread 24–48 hours after emergence. A number of larvae and pupae were preserved in 70% ethanol at the time that they were received from Argentina.

Adults were examined with a Nikon SMZ-U stereomicroscope with fiber-optic ring-light illumination at magnifications of 7.5–75×. Genitalia dissection and



FIGS. 1–4. *Nanodacna austrocedrella* adults. **1**, Holotype ♂, # CNC LEP 00001116; **2**, Paratype ♀, # CNC LEP 00001137; **3**, Paratype ♀, # CNC LEP 00001141, palest specimen of the type series; **4**, Paratype ♀, # CNC LEP 00001138, darkest specimen of the type series.

preparation followed Landry and Wagner (1995) except that Orange G was used exclusively as a stain in male preparations, and a combination of orange G and chlorazol black was used for female genitalia. Due to the highly tridimensional aspect of the male genitalia, some dissections were mounted whole and unaltered while others were separated on one side and “unrolled” to expose the most diagnostic features. Dissections were studied using a Nikon Eclipse E800 compound microscope at magnifications of 40–400×, in pure lactic acid on well slides and in Euparal on permanent slide mounts. To examine venation, wings were detached, wetted in 70% ethanol, bleached in diluted sodium hypochlorite (Javex®) for a few seconds, rinsed thoroughly in 30% ethanol, stained with orange G in lactic acid, dehydrated, and mounted in Euparal on slides.

The ultrastructure of the larva and pupa was studied with an Amray 1810 scanning electron microscope at an accelerating voltage of 10 kV. For SEM examination, immature specimens were cleaned in 10% ethanol with a camel-hair brush, dehydrated in increasing concentrations of ethanol to absolute ethanol. After dehydration, specimens were critical-point dried using a Tousimis critical-point dryer, mounted on SEM stubs, and coated with gold-palladium (40/60%), using a Cressington sputter coater. All measurements were made using a dissecting microscope with a calibrated

micrometer or generated by the electron microscope.

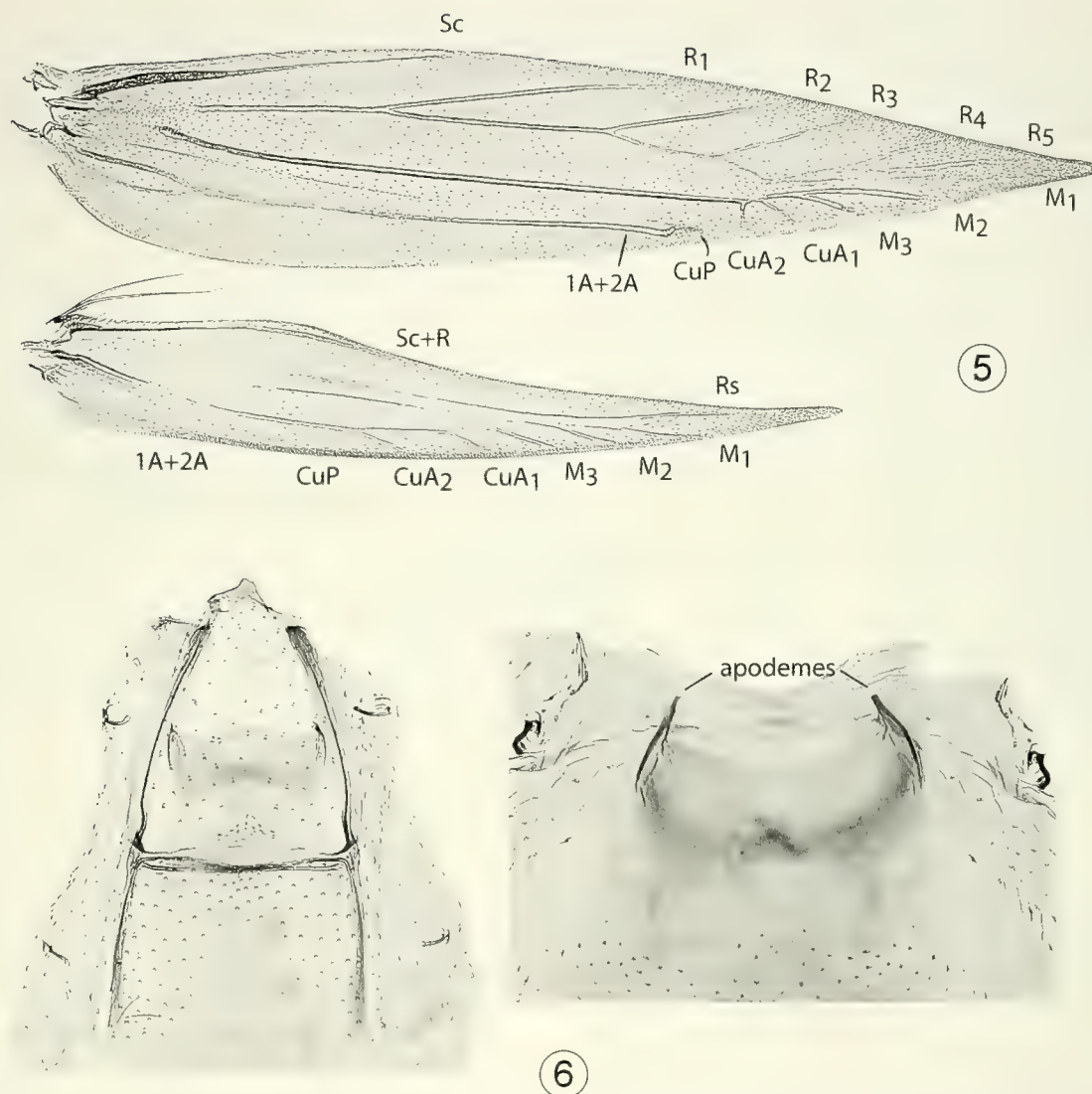
Photographs of adults and genitalia were taken with a Nikon DMX 1200 digital camera mounted on either Nikon microscope mentioned above. All images were subsequently processed with Adobe Photoshop®. For line art, hand-drawn sketches were digitized and processed in Adobe Illustrator® as scalable vector graphics.

The holotype and adult paratypes are deposited in the Canadian National Collection (CNC), Ottawa. Paratypes are also deposited in the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” (MBR), Buenos Aires, the National Museum of Natural History (USNM), Washington, D.C., the Natural History Museum (BMNH), London, and the Zoologisk Museum (ZMUC), Copenhagen, Denmark.

***Nanodacna austrocedrella***  
**Landry & Adamski, new species**

**Diagnosis.** Adults are small, fuscous brown to dark-brown moths with a slightly peppery appearance from the suffusion of dark scales over the creamy-white ground color (Figs. 1–4). The forewing bears three black spots of slightly raised scales in both sexes. The male has small, compact genitalia with an elongate-rectangular, hood-like tegumen, broad valvae with a deeply sinuate ventral margin, a large, inwardly directed





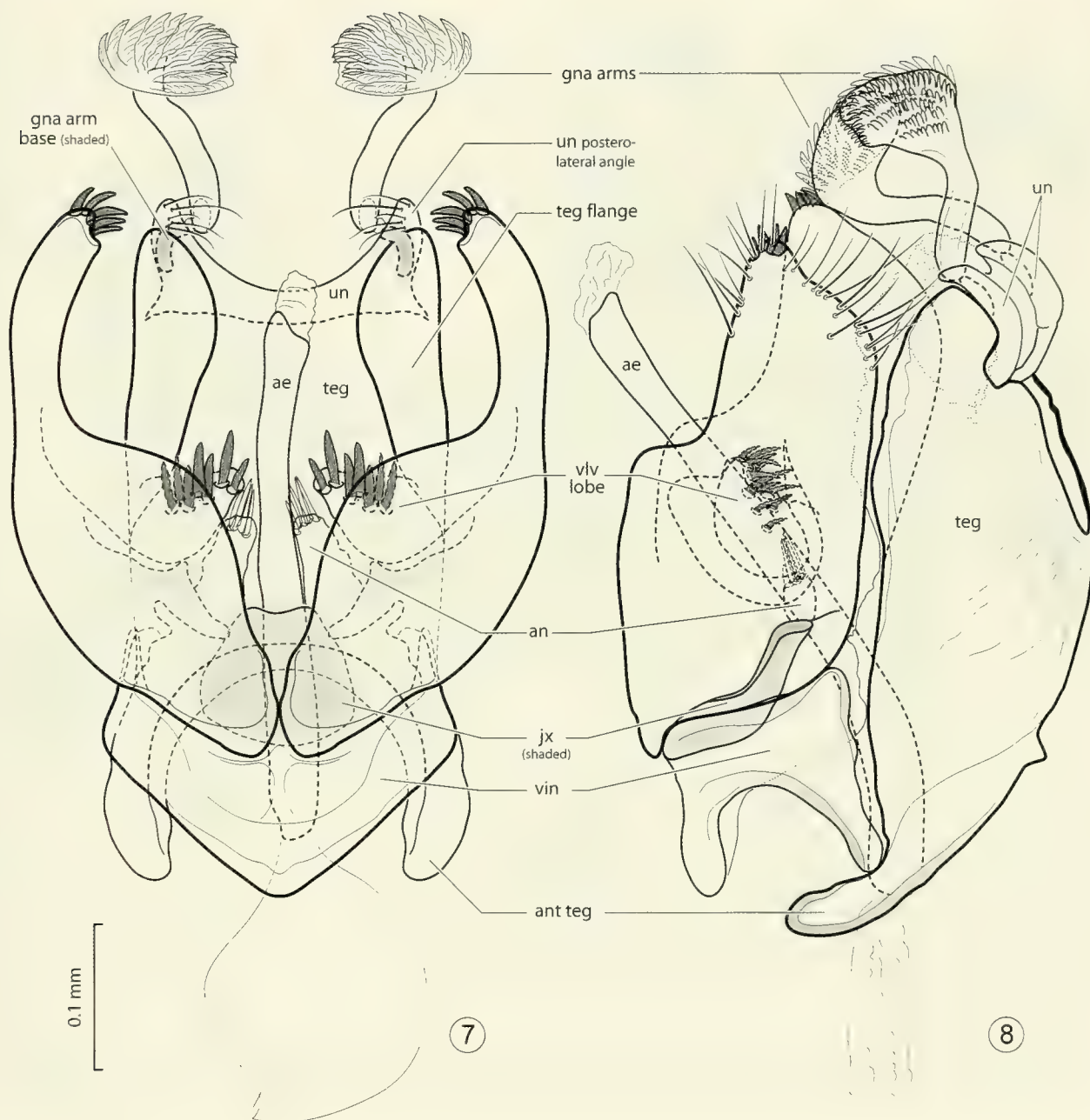
FIGS. 5–6. *Nanodacna austrocedrella*. 5, ♂, wing venation (slide MIC 4767); 6, Basal segments of abdomen; left: ♂ T1–T2 (slide MIC 4699); right: ♀ S1–S2 showing apodemes (slide MIC 4768).

spinose process projecting from the costal margin and abutting the middle of the aedeagus, and a small cluster of short spines at apex (Figs. 7–9). In overall aspect, the genitalia have an appearance generally resembling that of *Homoeoprepes felisae* Clarke (from Colombia; figured in Clarke 1962, Fig. 4) but in the latter, the costal process of the valvae is not projected, the ventral margin of the valvae is evenly rounded and without an apical spine, and the paired arms of the gnathos are proportionally shorter with their rows of flat spines covering half their length. The female genitalia of *N. austrocedrella* (Figs. 10–14) are very simple with few remarkable features and resemble quite closely those of *H. trochiloides* Walsingham (from Costa Rica; Fig. 1 in Clarke 1962); the 8th abdominal segment is undif-

ferentiated and mostly membranous, the ostium is small, indistinguishable, and situated submedially on S8, the ductus bursae is rather straight with a slight sclerotization near the inception of the ductus seminalis, the corpus bursae is elongate-ovoid with a pair of weakly developed signa in the distal portion of the bursa. Despite a general resemblance in their genitalia, *N. austrocedrella* and *Homoeoprepes* species are moths with very different habits and do not occur in the same geographic area (but see discussion below).

**Description. Adult.** (Figs. 1–4). **Forewing length** 4.0–5.1 mm, mean = 4.6, SD = 0.30; **wingspan** 8.7–11.3 mm, mean = 10.2, SD = 0.69 (n = 32). Moth with creamy-white ground color heavily suffused with dark-brown- to rusty-brown-tipped scales.

**Head** creamy-white, with dark-brown scales narrowly lining each side of frons; a few scales around eyes with fuscous tips; scales of



FIGS. 7, 8. *Nanodacna austrocedrella* male genitalia, both drawn from slide MIC 4765. **7**, Ventral aspect, setae of valvae omitted; **8**, Lateral aspect, setae of uncus and of left valva omitted. Abbreviations: ae = aedeagus; an = anellus; ant teg = anterolateral arm of tegumen; gna = gnathos; jx = juxta; teg = tegumen; un = uncus; vin = vinculum; vlv = valva.

frons and vertex spatulate, appressed, arranged in fan from each side around eyes meeting along middle of vertex. Labial palpus upcurved with apex extended to top of vertex, third article nearly as long as second and creamy-white with some dark-brown near tip; second article dark-brown on outer side. Haustellum base with creamy-white scales. Antenna with scape creamy-white, with pecten of 20–25 fili-form scales in both sexes; flagellum extended to two-thirds to three-quarters of forewing, with alternating creamy-white and dark-brown annulations throughout.

Dorsum of thorax with creamy-white ground color overlaid with fuscous-tipped scales. **Forewing** upper surface with creamy-white ground color densely suffused with fuscous to dark-brown-tipped

scales; with three small patches of raised black scales, two near middle of wing, and one at end of cell in distal third on termen, each patch surrounded by narrow area of creamy-white; fringe scales pale-fuscous gray; underside gray white suffused with fuscous to dark-brown scales, margin around termen contrastingly paler, creamy to creamy-white; lanceolate, stigma absent; R4 and R5 stalked, R5 to anterior margin; M1 connate with R4–R5; M2 to CuA2 connate; CuP obsolete (Fig. 5). **Hindwing** and its fringe pale gray to pale fuscous gray; narrowly lanceolate, anterior margin bulged before middle, concave in distal two-thirds; cell absent; Sc+R running very close to anterior margin to its middle; M1 to CuA2 separate; CuP and 1A+2A obsolete; female frenulum with two



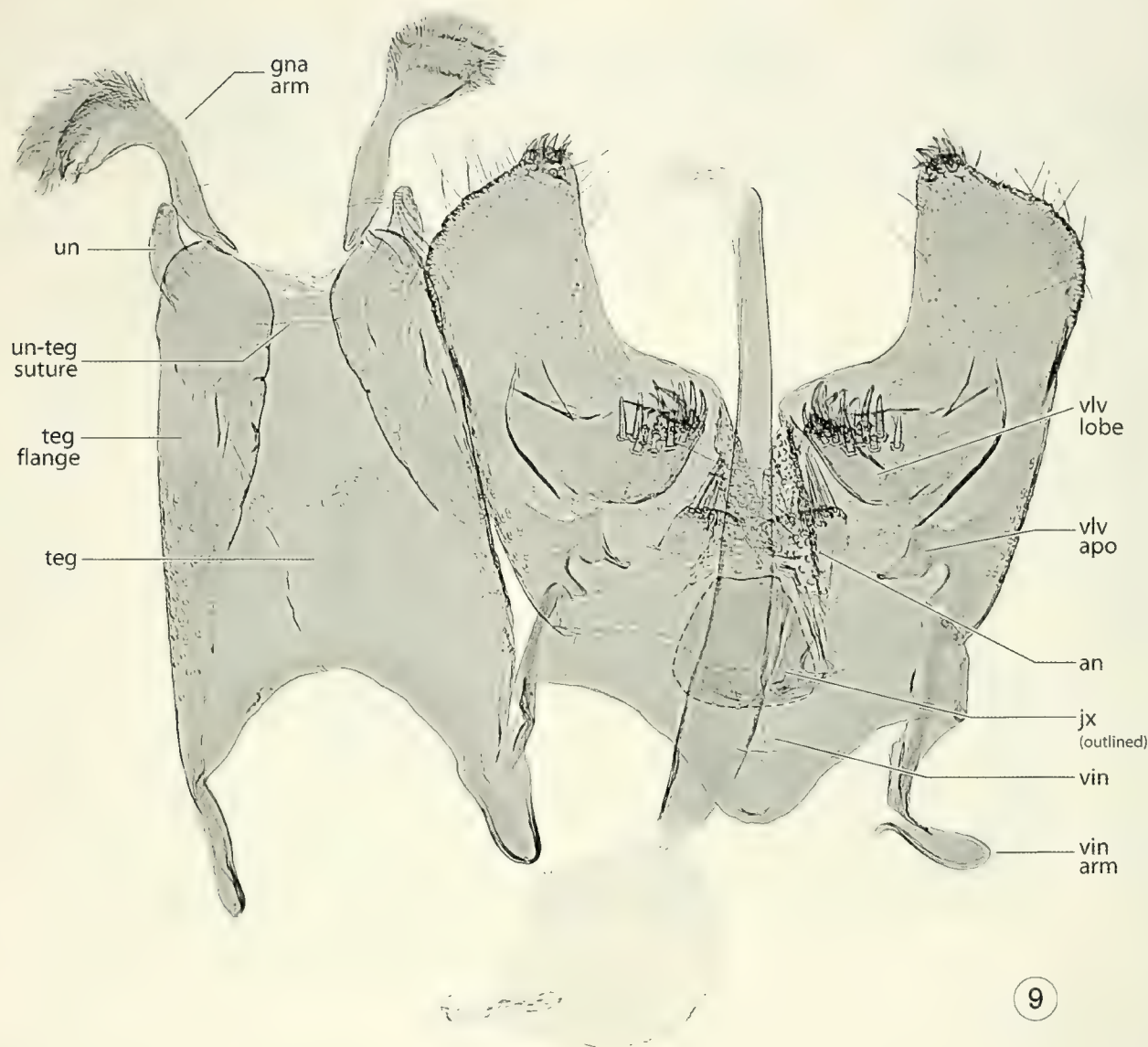


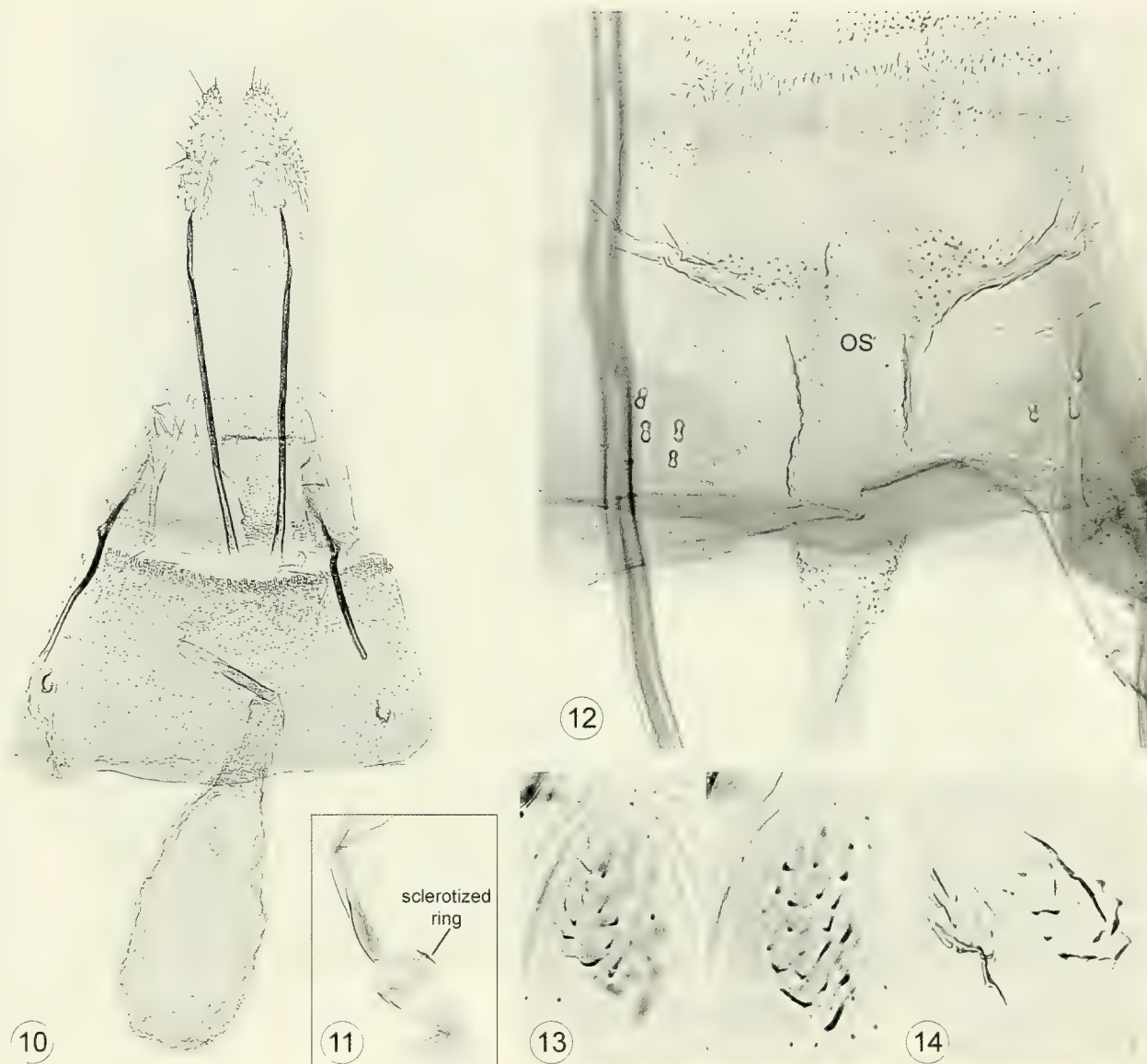
FIG. 9. *Nanodacna austrocedrella* male genitalia, slide MIC 4699, dorsal aspect with tegumen-uncus-gnathos complex separated on one side and "unrolled" to the left. Abbreviations: ae = aedeagus; an = anellus; ant teg = anterolateral arm of tegumen; gna = gnathos; jx = juxta; teg = tegumen; un = uncus; vin = vinculum; vlv = valva; vlv apo = apodeme of valva.

acanthae. Fore- and midleg with outer side dark-brown; tarsi with dark-brown annulations. Hindlegs entirely creamy-white to buff white, in some specimens tarsi with dark-brown annulations. Wing venation similar in every respect to that of *N. ancora* (described by Clarke 1964; Fig. 96 in Clarke 1965a), the type species of *Nanodacna*.

**Abdomen** entirely creamy-white or gray white; internally S1-S2 transverse, barely sclerotized, without distinguishable venulae, apodemes rudimentary (Fig. 6). Terga and sterna unmodified, membranous.

**Male genitalia** (Figs. 7-9) compact. Tegumen elongate-rectangular, parallel-sided in dorso-ventral aspect, dorsally only slightly convex; sides inwardly folded so that ventrally tegumen is semi-closed and forms a broad gutter around anal tube. Uncus, a narrow, crescentic band fused to distal margin of tegumen (line of

fusion distinct); lateral angles protruded as slightly incurved, kernel-shaped lobes with short, fine setae. Gnathos reduced to a pair of narrow, articulated, dangling arms that are about one-third length of tegumen; apex of each abruptly enlarged forming an ovoid knob with 8-10 crescentic rows of spinules. Vinculum a transversely narrow, V-shaped arch with lateral arms extended dorsally, articulating with downcurved anterior arms of tegumen. Valvae stiffly articulated to vinculum, short and broad, with ventral margin deeply sinuate near middle; distal portion sparsely setose marginally; apex with cluster of short spiniform setae; medially with a large, inwardly projected process terminated by a cluster of stout setae that abuts the aedeagus at level of anellus; anterodorsal angle developed into elaborately dissected apodeme attached to transtilla. Juxta present as trapezoid plate tightly attached (fused?) to middle of aedeagus, without projected lobes. Anellus developed as stiff, slightly sclero-



FIGS. 10–14. *Nanodacna austrocedrella* female genitalia. **10**, Genitalia, extended ovipositor and 7th segment (slide MIC 4766); **11**, Detail of anterior portion of ductus bursae and base of corpus bursae (slide MIC 4700); **12**, Details of sterigma and ostium bursae on S8 (slide MIC 4767); os = ostium; **13**, Signa, on left with focus on signum above, on right with focus on signum of same below (slide MIC 4766); **14**, Signa (slide MIC 4768).

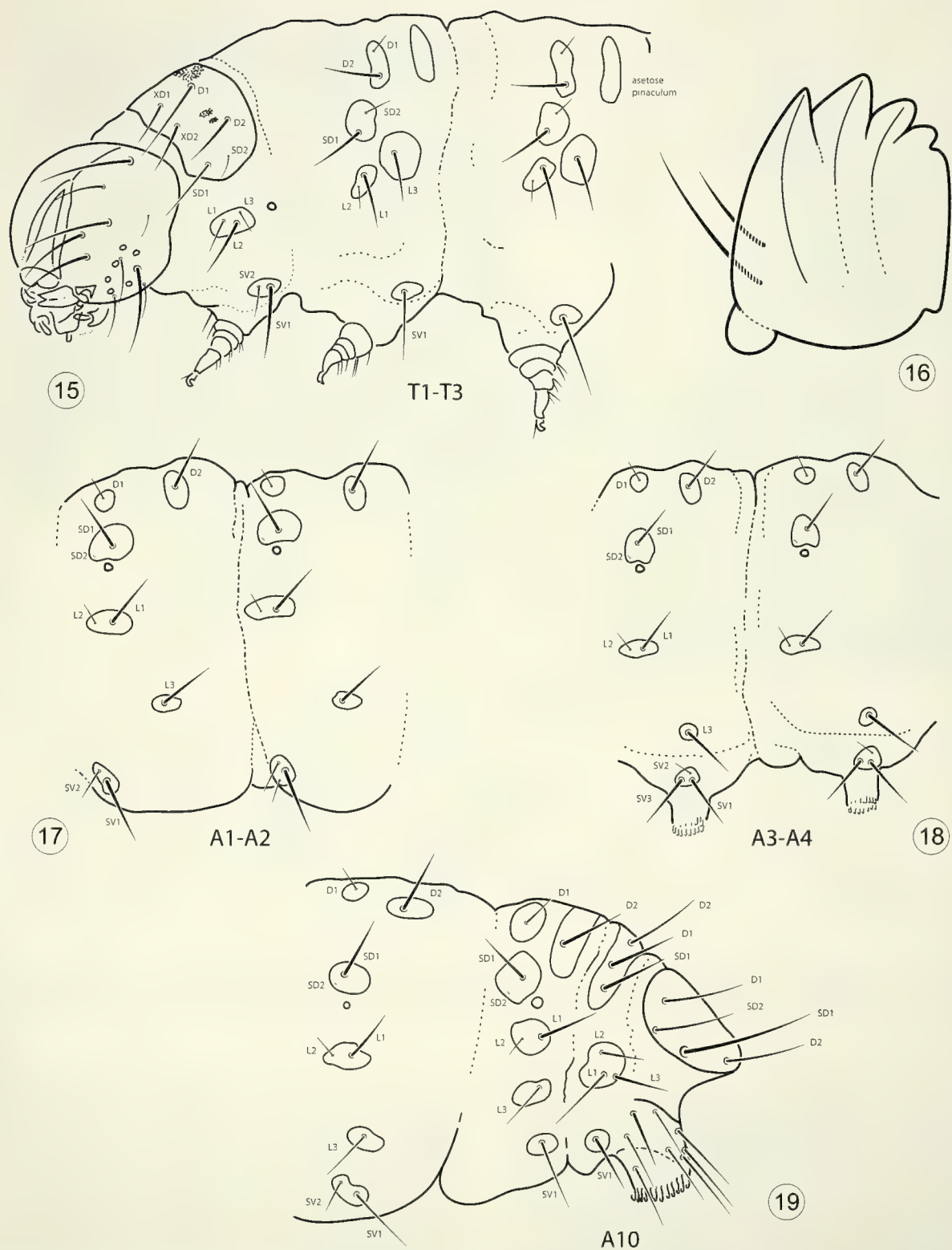
tized cone bracing middle of aedeagus, with cluster of stiff, short setae on each side slightly venterad of aedeagus axis. Aedeagus very slightly sigmoid (lateral aspect in situ) with apex upturned; anterior portion slightly bulged; semi-ankylosed by juxta-transstilla; cornuti absent.

**Female genitalia.** (Figs. 10–14). Ovipositor proportionally short,  $0.15 - 0.2 \times$  length of abdominal segments 1–7, papillae anales conical, membranous, finely setose. Posterior apophyses about  $1.5 - 2 \times$  length of anterior apophyses. T8 transversely rectangular, lightly sclerotized, with posterior margin lines with 10–15 fine setae. Ostium bursae situated slightly beyond anterior margin of S8. S8 membranous except for a small, lightly sclerotized transverse area on each side of ostium bursae. Colliculum and a funnel-shaped medial area of S8 distad of ostium finely spinulose. Ductus bursae narrow,

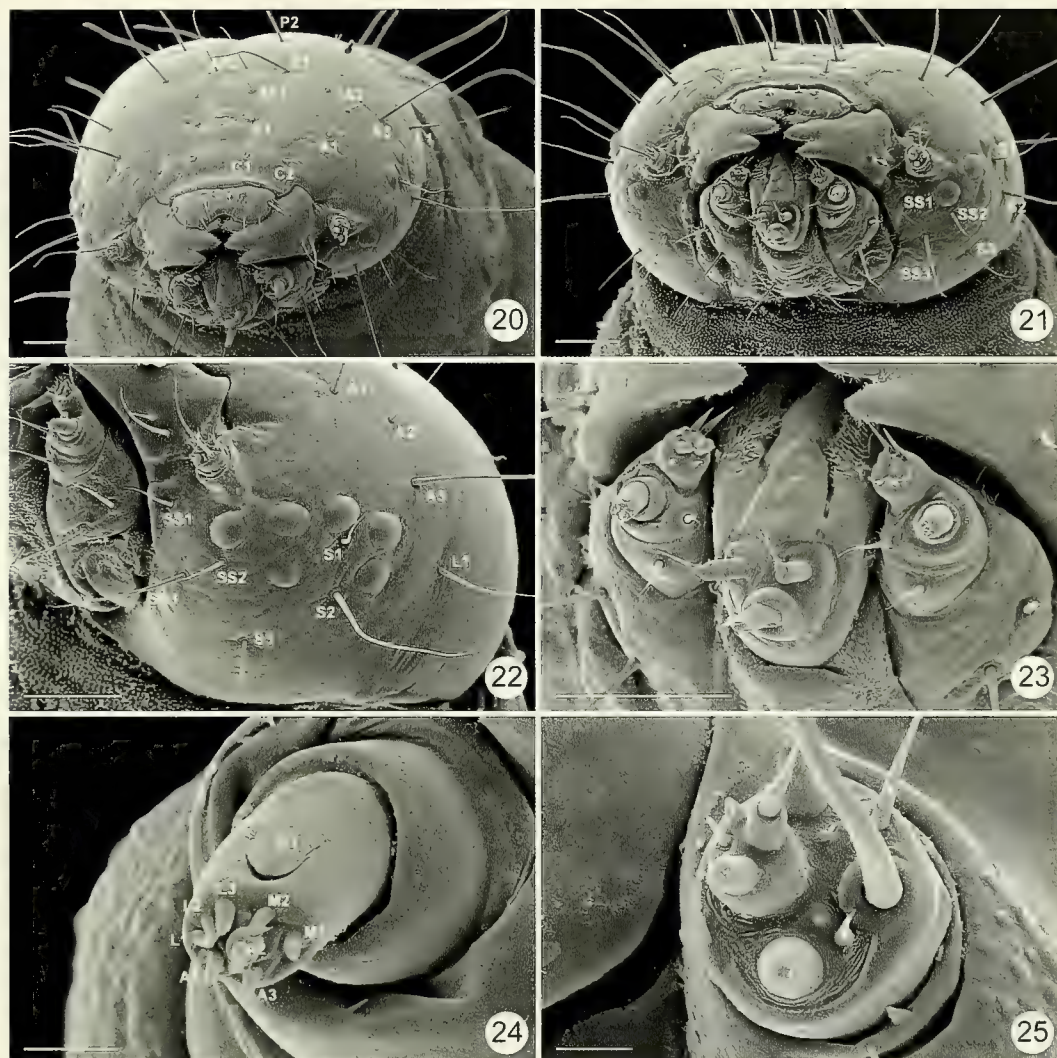
nearly straight (easily bends or twists in preparations), extended slightly beyond apices of anterior apophyses; inception of ductus seminalis situated at junction of corpus bursae and short sclerotized section on anterior end of ductus bursae. Corpus bursae finely spinulose, elongate-ovoid, broadest near anterior end; membrane thin and flimsy, with narrow, lightly sclerotized band forming an incomplete ring near posterior end (Fig. 11). Signa paired, weakly sclerotized; small patches of coarsely pointed microsculpture (obsolete in some specimens; Fig. 14).

**Variation.** The amount of dark suffusion of the forewings varies (Figs. 1–4), specimens with sparser fuscous suffusion appearing significantly paler overall (Fig. 3). The extent and distinctiveness of the three spots of raised black scales also varies, some spots being barely noticeable in some specimens. An appreciable amount of wear is





FIGS. 15-19. *Nanodacna austrocedrella* larval chaetotaxy. **15**, Head and thorax, lateral aspect; **16**, Mandible; **17**, Abdominal segments 1-2, lateral aspect; **18**, Abdominal segments 3-4, lateral aspect; **19**, Abdominal segments 8-10, lateral aspect.



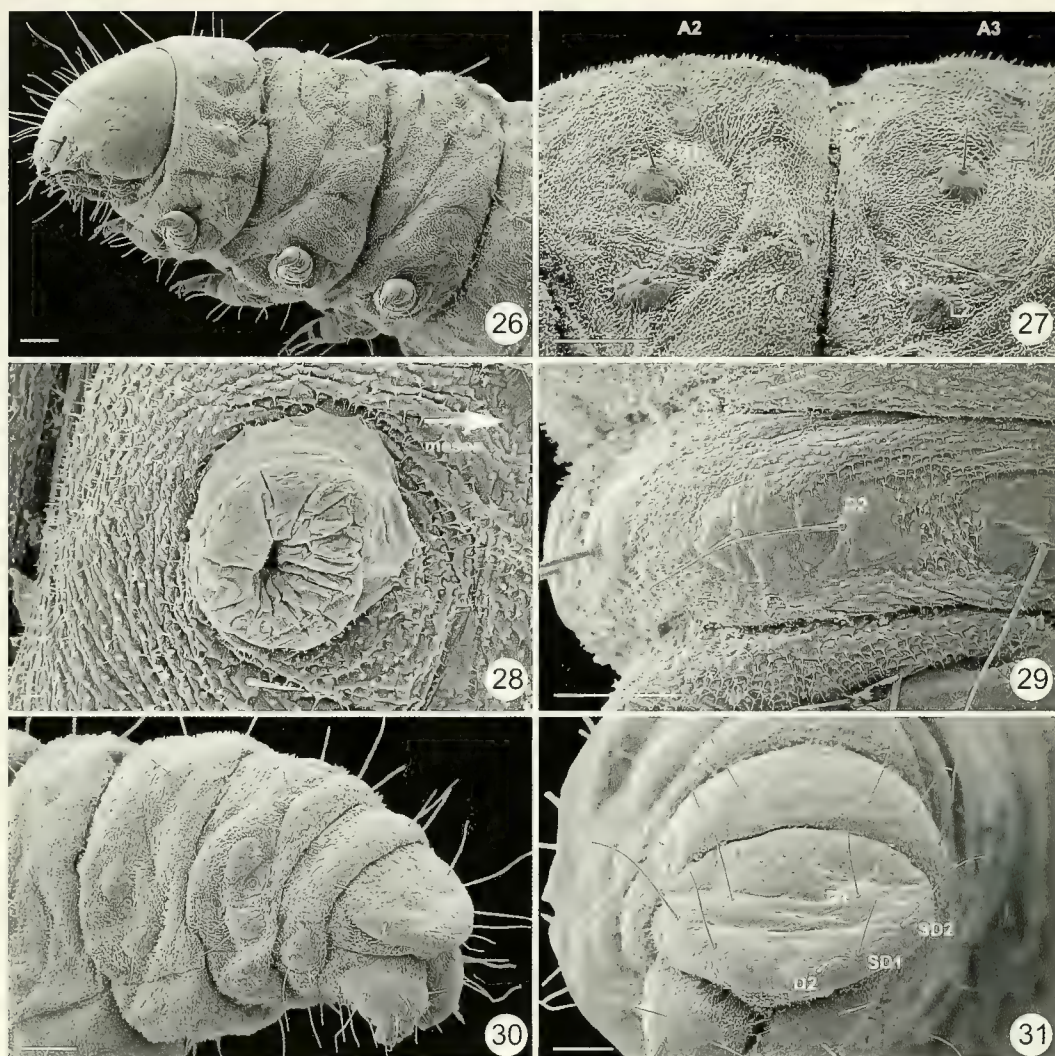
FIGS. 20–25. *Nanodacna austrocedrella* larva. 20, Head in dorsofrontal aspect; 21, Head in subventral aspect; 22, Head in anterolateral aspect; 23, Submentum and spinneret; 24, Maxillary palp; 25, Antenna.

present in many specimens of the type series even though they were reared and carefully mounted. This wear may have resulted in part from the fact that emerging adults must crawl out of their narrow pupal galleries in the bark of their host. Dead specimens tend to become greasy on the head and thorax after they have been pinned.

**Larva.** (Figs. 15–31): Length 0.9–3.4 mm [ $n = 112$ ]. Body pale yellowish brown, with a dense covering of short microtrichiae; pinacula and sclerites of the thoracic legs slightly darker; head capsule, prothoracic shield, anal plate, and crochets dark yellowish brown; spiracles on T1 and A8 larger than spiracles on A1–A7 (spiracle on A8 being the largest), spiracle on A1 slightly larger than those on A2–A7. Head (Figs. 15, 20–22, 26): hypognathous; epicranium relatively smooth, with few short transverse wrinkles; adfrontal sclerites broad, delimiting frons dorsolaterally; AF1 near apex, longer than AF2, frons closed, F1 in straight line with C1 (Fig. 20), slightly farther from C1 than C1 is from C2; P1 closer to AF2 than P2; P1 longer than P2; MD1 and MD2 (not shown) in area posterolateral to P2; labrum with distal emargination medially, forming two lateral lobes; each lobe with three pairs of setae, mesal and lateral pair subequal, median pair equal in length; labium with spinneret projecting slightly forward; apex of maxillary palpus (Fig. 24) with

sensilla arrangement and types similar to those of other gelechioids; six stemmata present and arranged as in Fig. 22. S1 close to stemma-1, S2 close to stemma-3, and S3 located in subgenal area distal to stemma-6; SS2 close to stemma-5, SS1 and SS3 along subgenal margin posterior to mandibular condyle; mandible with four prominent teeth and two subequal setae near base of condyle; sensilla types on antenna (Fig. 25) similar to those of other gelechioids. Prothorax (Fig. 15): shield with three pigmented spots, a large diamond-shaped spot on the posterior margin of middle, and two small, subequal spots near base of D2; XD1, XD2, and SD1 along submarginal area of anterior, SD1 about one-third longer than XD1 and XD2; SD2 short, posterolateral and proximal to SD1, anterior to D2 and D1; D1 longest seta on shield. L-group trisetose (some specimens bisetose, with L3 absent), L2 more than twice length of L1 and L3; L3 usually dorsad to L1 and L2; SV1 nearly  $3 \times$  length of SV2. Pterothorax (Fig. 15): D2 about twice length of D1, both on same pinaculum, an elongate pinaculum (without setae) posterior to pinaculum bearing D1 and D2; SD1 about  $2 \times$  length of SD2, both on same pinaculum anterior to pinaculum bearing D1 and D2; L2 in near straight line with SD1, about  $2\text{--}3 \times$  length of L2; L2 anteroventral to L1, both on same pinaculum; L3 dorsoposterior to L1;



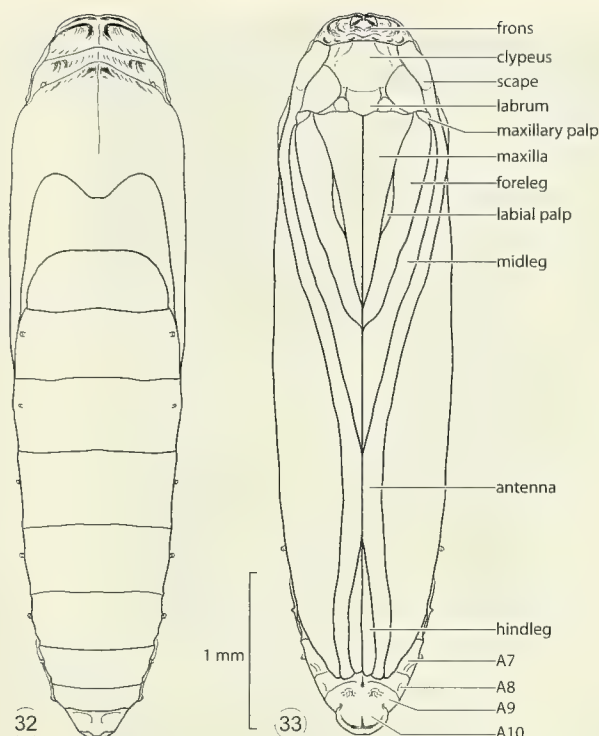


FIGS. 26–31. *Nanodacna austrocedrella* larva. Head and thorax in lateral aspect. 27, A2–A3, dorsolateral portion; 28, Proleg on A3; 29, A9 in dorsal aspect; 30, A7–A10 in lateral aspect; 31, A9–A10 in dorsal aspect.

SV1 in straight line with or slightly posterior to L3. Tarsal setae setiform. Abdomen: All V-group setae on A1–A10 equidistant: A1 and A2 (Figs. 17, 27): D2 about  $2 \times$  length of D1; D1 in near straight line with SD1; SD1 on large pinaculum slightly above spiracle; SD2 very short, indistinct; L1 slightly posterior to spiracle, about  $2 \times$  length of L2; L2 slightly anterior to spiracle; L3 ventral to and in near straight line with D2; SV-group bisetose on A1 and trisetose on A2. A3–6: (Fig. 18): setae as previous description of A1–A2, with SV-group trisetose, SV1 and SV3 of equal lengths, about  $3 \times$  length of SV2, and prolegs present, with crochets in uniordinal mesopenellipse. A7–A10 (Figs. 19, 30): A7 similar to description of A1–A2; A8 with D1 on separate pinacula, D2 setae on same elongate pinaculum; SD1 in near straight line with D1, dorsoanterior to spiracle; L2 and L1 on same pinaculum beneath spiracle; L3 posteroventral to L1–L2 pinaculum; SV-group bisetose, with SV1 about  $3 \times$  length of SV2; A9 with three pairs of setae; D2, D1, and SD1 on same elongate pinaculum; pinaculum extended to about level of dorsal rim of spiracle on A8; L-group trisetose, with L2 and L3 about equal in length and shorter than L1; SV-group unisetose; A10 shield (Fig. 31), with SD2, SD1, and D2 on submarginal area and D1 near mesoposterior area adjacent to SD2; crochets uniordinal.

**Pupa.** (Figs. 32–42): Length 1.9–2.2 mm [ $n = 10$ ], elongate, smooth, with shallow transverse wrinkles on the forebody, spiracles protuberant (Figs. 32–34), cuticle unspined. Ecdysial line extended from posterior margin of metathorax to anterior margin of vertex. Frontoclypeal suture complete; frontoclypeus truncate, with median subtriangular concavity flanked by 3–5 wide, rounded ridges; frons quadrate, ventral part of clypeus flanked by mandibular sclerites. Vertex with prominent anterior transverse ridge, extended laterally and medially, demarcating two lateral rectangular concavities (Fig. 36); vertex and prothorax divided by a transverse suture. Labrum U-shaped, broader at posterior margin. Labial palpi exposed. Maxillary palpi present. Maxillae extended to about one-third the distance to the caudal wing margin. Prothorax narrowed medially, posterolateral margin with small axillary tubercle (Figs. 37–38). Prothoracic femur exposed. Antennae, prothoracic legs, and mesothoracic legs convergent. Mesothoracic legs longer than prothoracic legs. Metathoracic legs exposed at their tips. Mesothoracic spiracle a small circular opening. Antennae and wing cases extended to and ventrally concealing A5–A8; A9 lateroventrally just beyond antennal apices with a pair of barely elevated bumps, each bearing a short transverse row of several distally-hooked setae (Figs. 41, 42), laterally with small cav-





FIGS. 32–33. *Nanodacna austrocedrella* pupa. 32, Dorsal aspect; 33, Ventral aspect.

ity set with a few distally-hooked setae (Figs. 39, 40); A10 rounded, without setae.

**Holotype** ♂: [label 1] “ARGENTINA, Chubut/ Futaleufu, Trevelin, Instituto/ Nacional de Tecnologia / Agropecuaria Estacion / Forestal, em. 27–28.IX.1997/ leg. M. Rajchenberg”; [label 2] “JFL lot no. 97–99/ in bark of *Austrocedrus chilensis*/ Larva–Pupa 8 Feb 1997”; [label 3, green] “genitalia slide ♂/ MIC 4765”; [label 4, blue] “Database #/ CNC LEP 00001116”; [label 5, orange] “HOLOTYPE ♂/ *Nanodacna austrocedrella*/ J.-F. Landry & Adamski/ CNC Type no. 22858” (CNC).

**Paratypes**, 14 ♂, 19 ♀ with database # CNC LEP 00001117–00001149.

11 ♂, 14 ♀ with same data as holotype except for adult emergence dates as follows: 4 ♂, 1 ♀, emerged 27–28 September 1997 (CNC ♀ slide MIC 4772); 7 ♂, 9 ♀, emerged 29–30 September 1997 (CNC ♂ slides MIC 4699, MIC 4763; CNC ♀ slides MIC 4766, MIC 4700); 2 ♀, emerged 3 October 1997; 2 ♀, emerged 6 October 1997 (CNC ♀ slide MIC 4767). (CNC, 2 in BMNH, 2 in MBR, 2 in USNM, 2 in ZMUC).

1 ♂, JFL lot no. 96–56, same locality data and host as holotype, larva collected 29 September 1996, leg. S. Rizzuto, C. Cuevas, emerged 27–28 September 1997 (CNC ♂ slide MIC 4764).

Argentina, Chubut, Futaleufu, Arroyo Los Rifleros, Propriedad “La106”, JFL lot no. 96–55, larvae collected 13 November 1996: 1 ♂, 1 ♀, emerged 27–28 September 1997 (CNC ♀ slide MIC 4768); 2 ♀, emerged 29–30 September 1997; 1 ♀, emerged 3 October 1997. (CNC).

Argentina, Chubut, Futaleufu, Los Cipreses, Propriedad “Pelmen”, JFL lot no. 96–100, larvae collected 10 April 1997: 1 ♂, 1 ♀, emerged 29–30 September 1997. (CNC).

**Other specimens examined.** The following four adult specimens are unpinning, rubbed and stored in microvials on pins, therefore they are excluded from the type series.

1 ♂: Argentina, Chubut, Futaleufu, Arroyo Los Rifleros, Propriedad “La106”, in pure stand of *Austrocedrus chilensis*, 13 November 1996, M. Rajchenberg (CNC).

3 ♀: Argentina, Chubut, Futaleufu, 50 km Esquel, “Los Cipreses”, 30 October 1995, C. Gomez (CNC).

Larvae and pupae. Same locality as holotype. 93 L, 8 January 1996: 99 L, 21 January 1996; 53 L, 8 February 1996; 17 L, 14 February 1996; 120 P, 26 April 1996; all leg. C. Gomez; in 70% ethanol (CNC).

**Type locality:** Instituto Nacional de Tecnologia Agropecuaria (INTA) Estacion Forestal, Trevelin, Departamento Futaleufu, Provincia de Chubut, Argentina.

**Etymology.** The specific epithet is derived from the generic name of the food plant, *Austrocedrus*.

## DISCUSSION

**Placement and relationships of *N. austrocedrella*.** The monophyly of the Agonoxeninae is weakly supported by homoplastic character states (Hodges 1998). The composition of the subfamily is far from settled, as evidenced by the recent transfer of a number of Neotropical species and genera previously scattered in other gelechioid families and groups (Hodges 1997, Becker 1999). Undoubtedly many undescribed species of this generally poorly known and little collected group remain to be discovered in the Neotropics. A number of changes of combination have also resulted from recent generic synonymies based on the study of hitherto poorly known Old World taxa (Sinev 1999).

*Austrocedrella* shares several features with other species of *Nanodacna*: similarly proportioned labial palpi, lanceolate wing shape, similar wing venation, lack of accessory cell in the forewing, male S1–2 without specialized pouch, similar range in body size. Clarke’s (1964) description of *Nanodacna* emphasized wing venation characters. The genus is somewhat heterogeneous in genital characters and *austrocedrella* differs in that respect from all of the included species.

In genital features, *austrocedrella* shares several similarities with species of *Homoeoprepes* Walsingham, a Neotropical genus noted by Clarke (1962) as having “a very close affinity” with *Nanodacna*. *Homoeoprepes* are otherwise larger moths (18–27 mm in wing expanse; 8–13 mm for *Nanodacna*) differing in overall appearance, wing venation and wing shape, proportions of the head and labial palpi, and in having a specialized pouch on abdominal sternites 1–2 in males. Clarke (1962) did not specify in what respect he considered these two genera to be closely related, but he indicated their differences in wing venation and shape, which are quite pronounced. He weighted venational characters heavily in defining the genera but gave no weight to wing shape. Curiously, he did not mention the affinity between these two genera in his 1964 paper describing *Nanodacna*, comparing it in-





FIGS. 34–42. *Nanodacna austrocedrella* pupa. 34, Lateral aspect; 35, Head, ventral aspect; 36, Head, dorsal aspect; 37, Lateral area of prothorax with axillary ridge; 38, Closeup of axillary ridge of fig. 37; 39, Lateral aspect of apex of wings showing small sublateral cluster of hooked setae; 40, Closeup of hooked setae of fig. 39; 41, Ventral aspect of lateroapical portion of abdomen showing one of the two setose bumps; 42, Closeup of the bump of fig. 41 showing hooked setae.

TABLE 1. Morphological characters of *Nanodacna* and *Homoeoprepes*. Features possessed by *australcedrella* are in bold.

	<i>Nanodacna</i>	<i>Homoeoprepes</i>
Labial palps	<b>third article about as long as second article</b>	third article about half as long as second article
Male S1–2	<b>without specialized structures</b>	with eversible lined sac with specialized scales
Vinculum	<b>broadened, expanded</b>	narrow, U-shaped band
Juxta	quadrate plate in <i>ancora</i> (type species), reduced in 1 species	<b>well developed quadrate plate</b>
Aedeagus	<b>upcurved or dorsally oriented apex</b>	nearly straight
Cornuti	present in 2 species ( <i>indiscriminata</i> , <i>vinacea</i> )	<b>absent</b>
Anellus	without dorsally projected lobes or undeveloped	<b>with pair of dorsally projected setose lobes</b>
Transtilla	with or without spined patches above aedeagus	<b>with spined patches above aedeagus</b>
Valva	without costal process or without patch of spines	<b>with costal process bearing patch of spines</b>
Valva	fused to vinculum in 2 species; free in <i>ancora</i> (type species)	<b>free</b>
Signa	pair of well defined ridged sclerites	<b>pair of faint, diffuse spinulate sclerites</b>
Ostium	with sclerotized sterigma	<b>sterigma membranous</b>
Wing shape	<b>lanceolate with narrow pointed apex</b>	broad and rounded apex in 2 species, narrowed in 1 species
Accessory cell	<b>Absent</b>	present
FW Venation	<b>M2 and M3 stalked R5 strong</b>	M2 and M3 separate R5 obsolete except at margin
	<b>R2 equidistant from R1 and R3</b>	R2 closer to R3 than R1
Number of features shared by <i>australcedrella</i>	7	8

stead to *Blastodacna* Wocke, a Holarctic genus that does not occur in the Neotropical region. Because none of these genera is phylogenetically defined and there is no phylogenetic analysis of other constituent genera of the Agonoxeninae, it is difficult to place *australcedrella* in any genus convincingly: shared features vary depending on the species considered in each genus (Table 1). This probably underlies the fact that a character analysis would result in a significant rearrangement of taxa. Characters of immature stages and life histories are unknown for *Homoeoprepes* and all species of *Nanodacna* except *australcedrella*, and thus cannot be used for placement. We chose to include *australcedrella* in *Nanodacna* by subjectively giving more weight to external adult features.

The genus *Nanodacna* was originally proposed by Clarke to accommodate two species of Agonoxeninae that he described from the Juan Fernandez Islands off the coast of Chile. Subsequently Clarke (1965b) also transferred to *Nanodacna* two other species previously described, namely *logistica* Meyrick from andean Argentina and *vinacea* Meyrick from amazonian Peru. With *australcedrella*, the genus now comprises five described species as follows:

#### *Nanodacna* Clarke, 1964:125

*ancora* Clarke, 1964:126; type species of *Nanodacna* by original designation and monotypy; Juan Fernandez Islands, Chile; type series examined (USNM); *australcedrella* Landry & Adamski, new species; Chubut Province, Argentina; *indiscriminata* Clarke, 1965a:93; Juan Fernandez Islands, Chile; type series examined (USNM); *logistica* (Meyrick, 1931:387) (*Colonophora*); combination by Clarke (1965b:563); Rio Negro Province, Argentina; holotype examined (BMNH); *vinacea* (Meyrick, 1922:574) (*Homaledra*); combination by Clarke (1965b:563); Rio Napo, Peru (not examined but illustrated in Clarke, 1965b:564).

In male genitalia *Nanodacna* is similar to other agonoxenine genera that have the gnathos as a pair of articulated rami each terminated in a lobe with rows or whirls of small spines, which is possibly a synapomorphy for these taxa (these are: *Amblytenes* Meyrick, *Araucarivora* Hodges, *Auxotricha* Meyrick, *Blastodacna* Wocke, *Chrysoclista* Stainton, *Dystebenna* Spuler, *Glaucacna* Forbes, *Heinemannia* Wocke, *Homoeoprepes* Walsingham, *Microcolona* Meyrick, *Spuleria* Hofmann, *Tocasta* Busck, *Zaratha* Walker). The gnathos of *Agonoxena* Meyrick and of *Pammeces* Zeller is configured differently; that of *Agonoxena* is composed of a single large median, spinose knob similar to that found in Depressariinae; that of *Pammeces* is a simple, V-shaped band without ornamentation. Inclusion of *Pammeces* in Agonoxeninae by Becker (1999) remains weakly supported.

**Significance of immature characters of *Nanodacna* within the Agonoxeninae.** Immatures of *N. australcedrella* are significantly different from published descriptions of Agonoxeninae, which are based primarily on taxa of the Northern Hemisphere. The most notable features of the immature stages of *australcedrella* are as follows. Larva: secondary setae absent; body covered with dense microtrichiae; T2–T3 each with a pair of aetose pinacula. Pupa: labial palpi



exposed; forebody without spicules; lateral abdominal condyles absent; "pupal legs" of A9 reduced to a pair of barely elevated bumps; antennae and wing cases ventrally extended to A9, concealing A5–A8.

Lack of secondary setae in the larva is a feature shared with *Araucarivora*, *Chrysoclista*, *Cladobrostitis* Meyrick, *Microcolona*, and *Haplochrois* Meyrick, which may be plesiomorphic for Agonoxeninae. Dense secondary setae are present in *Agonoxena* (Bradley 1966) and *Blastodacna* (Stehr 1987). The body of the larva is covered with dense microtrichiae, a feature shared with *Araucarivora*. Crochets are in a uniordinal mesopenellipside, which is the arrangement seen in other agonoxenines with known larvae. Presence of a pair of aetose thoracic pinacula is shared with *Haplochrois* (Kuznetsov 1916) and is a feature rarely seen in other Gelechioidea.

Labial palpi are exposed in the pupa of *N. austrocedrella*, a feature in which it differs from other Agonoxeninae. Lack of coarse spicules on the anterior half of the body from the vertex to the prothorax, such as found in *Araucarivora* (Hodges 1997), *Haplochrois*, and *Cladobrostitis* and *Microcolona* (Fletcher 1933), are a trait shared with *Blastodacna* and *Chrysoclista*. Unlike the pupae of several other agonoxenine genera [*Agonoxena* (Bradley 1966), *Araucarivora* (Hodges 1997), *Cladobrostitis* (Fletcher 1933), *Haplochrois* (Kuznetsov 1916, Bottimer 1926)], A9 of *N. austrocedrella* is without paired projected processes (the so-called "pupal legs" of authors; e.g., Hodges 1997). However, there is a pair of weakly elevated bumps bearing hooked setae that probably function as a cremaster. "Pupal legs" are likewise lacking in *Chrysoclista* which has A9 ventrally smooth, without hooked setae (pupae of *C. lineella* in CNC examined). The pupa of *N. austrocedrella* is proportioned differently from that of other agonoxenines, with the antennae and wing cases ventrally extended to A9 and concealing A5 to A8; other agonoxenines have proportionally shorter wing cases that leave A4 to A8 variously exposed ventrally.

In phylogenetic reconstructions of the Gelechioidea using parsimony analysis both Hodges (1998) and Passoa (1995) included Agonoxeninae in a clade of Gelechioidea defined by the presence of lateral condyles in the pupa, which restrict pupal abdominal movement to an up-and-down motion. However, this character is subject to homoplasy. Except for *Araucarivora* (Hodges 1997), Agonoxeninae pupae have poorly developed lateral condyles (Bradley 1966, Bottimer 1926, Fletcher 1933, Kuznetsov 1916, Sinev 1979). *Nanodacna austrocedrella* represents an example where condyles are absent. This suggests that reduc-

tion of pupal lateral condyles is probably a synapomorphy of the Agonoxeninae, although this loss has occurred several times in related outgroups (*Coelepoeta* Walsingham, *Xyloryctinae*, and *Peleopodinae* [Common 1990, Passoa 1995]).

The *N. austrocedrella* pupa displays several unusual specializations, some of which are unique among known Agonoxeninae and may be apomorphic and, thus, not informative phylogenetically. Other features may be indicative of relationship or homoplastic. More cogent statements of relationships will require a detailed character and cladistic analysis, which is beyond the scope of this paper, as well as discovery of the immature stages of additional agonoxenine taxa.

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## FUNCTIONAL GROUPS AND SPECIES REPLACEMENT: TESTING FOR THE EFFECTS OF HABITAT LOSS ON MOTH COMMUNITIES

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**ABSTRACT.** Species replacement, or the process whereby species from the surrounding landscape colonize a habitat remnant and potentially offset species loss, is gaining attention as an alternative mechanism to species impoverishment following habitat destruction. The challenge for butterfly and moth ecologists, however, is to devise analytical approaches that will identify species replacement and predict lepidopteran community structure following habitat alteration. The traditional approach to defining functional groups of Lepidoptera based on resource specialization is limited in these two regards. Here I propose a new approach to defining functional groups for moth communities in temperate deciduous forests that more explicitly incorporates information regarding host-plant type rather than resource specialization per se. In studies of moth diversity in temperate forest fragments, use of the proposed functional groups detected significant species replacement across a range of habitat area for moths in some forest regions but not others. The traditional approach to assigning lepidopterans to functional groups lacked sufficient power to detect species replacement regardless of region. I suggest that our ability to predict the effects of habitat loss on butterfly and moth communities will be greatly improved by adopting a functional group classification based on host-plant types rather than niche or diet breadth.

**Additional key words:** community composition, diversity, fragmentation.

Habitat loss is widely regarded as the single greatest threat to the diversity of terrestrial plant and animal communities worldwide (Fahrig 2001). Some field studies, however, have suggested that if only species richness is measured, the effects of habitat loss on forest lepidopteran communities may appear rather innocuous. For example, a number of studies have revealed that small patches of forest habitat are capable of supporting nearly as many butterfly and moth species as larger patches, and that this pattern appears in both temperate and tropical ecosystems (Brown & Hutchings 1997, Ricketts et al. 2001, Summerville & Crist 2003). It would be false, however, to conclude that large and small forests contain similar communities. Rather, in these butterfly and moth communities, habitat loss seems to be correlated with both (i) a reduction in the number of species dependent on forest interior habitat and (ii) the occurrence of a greater number of edge-tolerant species in smaller habitat remnants. Thus, habitat loss may contribute to species replacement; species identity within communities changes in response to variation in habitat size while species richness remains constant.

Species replacement is a relatively new explanation for describing patterns in lepidopteran communities following forest disturbance or habitat loss (Summerville & Crist 2002a). Historically, the dominant theoretical approach for predicting the numbers of species found in woodlots of different size invoked expectations from the theory of island biogeography (Usher & Keiller 1998). The development of landscape ecology theory, however, emphasized that species from the matrix surrounding patches of forest habitat could contribute species to the focal community (Magurran 1985, Holt 1993). For example, when moth species from the matrix habitat surrounding

smaller forest patches colonize forest edges, the subsequent gain in species may offset any loss of species dependent on forest interior habitat (Summerville & Crist 2003). Thus, moth communities in smaller woodlots appear disproportionately comprised of species with larvae known to feed on herbaceous vegetation, while larger forests are dominated by woody-plant feeders. This is an example of an extreme case of species replacement compared to others which document species turnover along a seral gradient (e.g., Steffan-Dewenter & Tschamntke 1997). In our study, species from different functional groups replaced one another along a gradient of increasing habitat loss. Thus, herbivory by lepidopterans shifted from the canopy to the understory layers in smaller woodlots.

In practice, documenting species replacement in butterfly or moth communities following habitat loss is not as simple as merely determining that large and small patches contain the same number of species; species replacement also requires that community composition differ in systematic ways. Measuring or describing changes in community composition following disturbance are not new for studies of Lepidoptera (e.g., Hill et al. 1995, Intachat et al. 1997, Usher & Keiller 1998, Horner-Devine et al. 2002). What is needed now are techniques that allow ecologists to tease apart how and why compositional shifts occur (Bierregaard et al. 2001). This last piece of information will allow ecologists to predict how much lepidopteran community structure will change in response to varying levels of disturbance or habitat loss (Summerville & Crist 2002a). Meeting this goal will be facilitated if lepidopterists expand their understanding of functional groups. Specifically, I argue that we must move away from defining lepidopteran guilds or functional groups solely using degree of resource specialization.

Instead, we should adopt a functional group classification created from our understanding for how different species utilize resources within different habitats.

#### LEPIDOPTERAN FUNCTIONAL GROUPS: TRADITIONAL APPROACHES

Traditionally, functional groups for butterflies and moths have been defined using a co-evolutionary approach based on the degree of specialization of the caterpillar to particular host-plant resources (Hunter 1991). The most commonly employed functional group classification acknowledges three primary assemblages: specialists, oligophages, and generalists. Specialists are usually defined as those Lepidoptera with caterpillars that utilize host plants of a single species or genus, oligophages use multiple plant species within a single family, and generalists are more cosmopolitan feeders (e.g., Steffan-Dewenter & Tschamtkke 1997, Lepš et al. 1998). Of all three functional groups, the assignment of species to the level of oligophage tends to be the most variable, rendering comparisons among studies by different authors problematic (Hawkins & MacMahon 1989). Research adopting a traditional approach to functional group classification generally predicts that changes in habitat will be correlated with a reduction in the number of specialists within the community (see Summerville et al. 2002 and citations within). Thus, the traditional format for constructing functional groups is useful for predicting species' vulnerability to habitat change relative to their niche breadth.

Restricting functional group ranks to specialists and generalists, however, has proven problematic when interest lies in detecting species replacement or in predicting how changes in lepidopteran communities affect ecosystem function. Specialist Lepidoptera do not always show the most adverse effects of changes in forest habitat due to differences in plant composition or disturbance regimes (Lepš et al. 1998, Summerville & Crist 2002a, b). For example, even when specialists and oligophages are disproportionately lost from a forest patch following habitat loss, matrix-dwelling species with similar diet-breadth may be equally likely to occur in small woodlots from the surrounding landscape (Summerville & Crist 2003, in press). Species replacement will be obscured at the level of the functional group when an equal number of specialists are present in large and small forests. Detection of replacement will require an examination of changes in the occurrence of individual species, an inefficient process for hyper-diverse communities. This is not meant to imply that defining lepidopteran functional groups based on diet-breadth has no place in ecologi-

cal research, just that it may not be the most powerful approach to detecting species replacement or predicting post-disturbance community structure in Lepidoptera (Summerville & Crist 2002b).

#### LEPIDOPTERAN FUNCTIONAL GROUPS: A NOVEL APPROACH

Detecting the occurrence of species replacement for lepidopteran communities requires a novel approach to functional group classification. One method employed in studies of tropical forest Lepidoptera is to use a single functional group as an indicator of entire community diversity. For example, a number of studies have quantified the effects of habitat loss on frugivorous butterfly species as a surrogate for overall butterfly diversity (Beccaloni & Gaston 1995, DeVries et al. 1997). While discovering surrogate taxa is a useful technique for simplifying the species diversity of tropical forest lepidopteran communities, it offers less promise as a method for detecting species replacement because surrogates are often selected to mimic the response of an entire community. Thus, ecologists identify surrogate taxa by demonstrating that a significant correlation exists between changes in diversity of the species within a particular functional group and the total species richness within a community (i.e., both should respond negatively to habitat loss). Under conditions of species replacement, however, total species richness remains unchanged following a disturbance such as habitat loss.

Horner-Devine et al. (2003) come close to demonstrating species replacement in Costa Rican butterfly communities. The authors reach the conclusion that butterfly communities within coffee habitats and within Las Cruces Reserve differ in species composition but not species richness. Species replacement is suggested in Table 1 of Horner-Devine et al.; coffee habitats support a greater number of frugivorous Charaxinae and Nymphalinae than Las Cruces Reserve. Yet, both the reserve and coffee habitats contain roughly the same total number of frugivorous and non-frugivorous butterfly species. Species turnover occurs within each guild between coffee plantations and reserve forests, but non-frugivores do not replace frugivorous butterflies in more disturbed habitats. Therefore, this guild classification does not appear to be very amenable to identifying species replacement. Some form of species replacement is likely to occur in Neotropical forests following habitat disturbance or loss (Bierregaard et al. 2001), yet identification of the process might be expedited by using a different approach to classification of functional groups.

Recent research in temperate forest ecosystems



suggests that classifying moth species into functional groups based upon the life form of the host resource is a promising way to test whether species replacement occurs in fragmented landscapes (Summerville & Crist 2002a, 2003, in press). This classification produces roughly 5 guilds of forest moths: woody-plant feeders (e.g., many Noctuidae: *Catocala* spp.), herbaceous feeders (e.g., Noctuidae: *Papaipema* spp.), dead/de-caying vegetation feeders (e.g., Noctuidae: *Zanclog-natha* spp.), encrusting flora feeders (e.g., fungi, lichens, mosses; e.g., many Arctiidae: Lithosiinae), and generalized feeders that use  $\geq 2$  functional categories (e.g., Noctuidae: *Agrotis ipsilon* Hufn.). Functional groups based on life forms should provide lepidopterists with novel insights into how moth communities change during succession, in response to disturbance, and following habitat loss. In addition, this method of defining functional groups will allow ecologists to make explicit connections between changes in lepidopteran communities and forest architecture after habitat loss. Similar approaches to defining functional groups were developed long ago by plant ecologists (e.g., Raunkiaer 1937) and several have proven useful when describing species replacement in floras such as described for Amazonian forest fragments (e.g., Bierregaard et al. 2001).

#### FUNCTIONAL GROUPS, HABITAT LOSS, AND SPECIES REPLACEMENT

Indeed, the proposed functional group classification was recently used both to detect species replacement in temperate forest moth communities and to elucidate the moth assemblages among which functional species replacement occurs (Lepš et al. 1998, Summerville & Crist 2002a, 2003). For example, in forests of the unglaciated Western Allegheny Plateau ecoregion of Ohio, species replacement was observed across a gradient of forest stand sizes (Fig. 1a). Using linear regression, I determined that the number of moth species with woody host-plants dwindles as forest habitat size decreases ( $df = 1$ ,  $R^2 = 0.58$ ;  $p \leq 0.05$ ). The overall reduction in moth species richness is partially offset because smaller forests gained additional species of herbaceous-plant feeders ( $df = 1$ ;  $R^2 = 0.73$ ;  $p \leq 0.01$ ). Species replacement, however, is not a ubiquitous process structuring forest lepidopteran communities. In historically glaciated forests of the North Central Tillplain ecoregion in Ohio, reduction in forest area is not correlated with an increase in herbaceous-feeding moth species (Fig. 1b). In these forests, habitat loss significantly reduces only woody-feeding species ( $df = 1$ ,  $R^2 = 0.80$ ,  $p \leq 0.01$ ).

It is important to emphasize that these trends would not have been observed if I had relied on an analysis

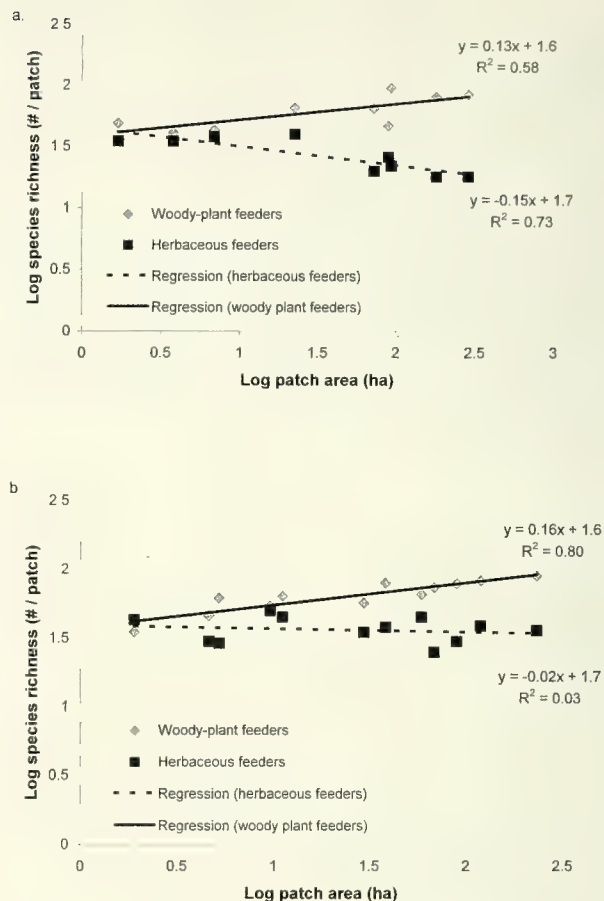


FIG. 1. Responses of species richness of moths that feed on either woody plant or herbaceous vegetation as caterpillars to variation in forest habitat area (ha). **a**, species replacement is observed in forests of the unglaciated Western Allegheny Plateau, but **b** in the historically glaciated North Central Tillplain, loss of forest habitat is only correlated with a decrease in species richness of woody plant feeders. Figure is modified from Summerville and Crist (in press).

framework grounded in testing hypotheses using the more traditional approach to guild classification. Out of the 344 moth species classified as either woody-plant feeders or herbaceous feeders, only 47 would have been considered specialists (i.e., species feeding only on host plants within a single genera), with the numbers of specialists split nearly evenly between woody plant feeders found in large forests and herbaceous feeders restricted to smaller woodlots (21 and 26 species respectively). Greater than 67% of the remaining species would have been considered generalists; thus the distribution of feeding strategies is strongly skewed to the generalist life history. In a different study designed to test for the effects of timber extraction on moths classified as either specialist or generalist, Summerville and Crist (2002) demonstrated that both functional groups responded negatively to timber harvest. Again, specialists were outnumbered by generalist species by nearly 4 to 1, render-

ing the power of the statistical test for a disproportionate response by specialists very low (KSS unpublished data). Therefore, for temperate moth communities, the traditional method of assigning species to functional groups appears to have limited potential to detect species replacement or differential responses of specialists to habitat disturbance. The question of why replacement occurs in some forest moth communities and not others remains to be explored, but the answer may be related to land use history or matrix vegetation type. Summerville and Crist (2003, in press) offer additional explanations for the factors contributing to species replacement in temperate deciduous forests.

### CONCLUSIONS

In conclusion, lepidopterists need not feel confined to testing ecological hypotheses within the framework of traditionally defined functional groups. Rather, I suggest that alternative classification schemes for lepidopteran functional groups will allow lepidopterists to test more powerfully hypotheses regarding species replacement and the post-fragmentation responses of moth communities to habitat loss. Currently, Lepidopterists may be confined in extending the concepts outlined in this paper to tropical ecosystems, as host plant data is lacking for the immature stages of many species, including butterflies. As a general rule, the definition of ecologically-relevant functional groups should be tailored to the ecosystem in question and should be created with regard to the natural history of focal taxa (Hawkins & MacMahon 1989, Summerville & Crist 2002b). In temperate deciduous forests, I believe adopting a classification scheme based on the life form of the host-plant holds considerable promise, and has been used successfully in plant ecology. That habitat loss affects communities of butterflies and moths worldwide is not a new observation for lepidopterists. What are required now are predictive models that will allow ecologists to forecast how lepidopteran communities are likely to change in the face of anthropogenic disturbances. Developing an improved understanding of the mechanisms of species replacement will move conservation biology one step closer toward such a goal.

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## THREE NEW SPECIES OF *LEPTEUCOSMA* DIAKONOFF (TORTRICIDAE: OLETHEUTINAE: EUCOSMINI) FROM INDIA

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**ABSTRACT.** Three new species of *Lepteucosma* are described from India: *L. ferruginoptera*, *L. alferdi* and *L. byuni*. We present detailed descriptions of adult morphology, wing venation and external genitalia.

**Additional key words:** Taxonomy, Genitalia, *ferruginoptera* sp. nov., *alferdi* sp. nov., *byuni* sp. Nov.

Owing to unique characters of the wing venation and male genitalia, Diakonoff (1971) proposed the genus *Lepteucosma* with *L. oxychrysa* Diakonoff as its type-species. *Lepteucosma oxychrysa* was represented by its holotype known only from Gilgit (Kashmir). In addition to the type-species, the genus is represented by seven more species: *L. blanda* (Kawabe) (Thailand), *L. ceriodes* (Meyrick) (Assam, Khasi Hills), *L. huebneriana* (Kocak) (Europe), *L. lutescens* (Razowski) (Afghanistan), *L. oxychrysoides* Kuznetsov (South Vietnam), *L. punjabica* Kuznetsov (India, Dharmshala, Punjab) and *L. siamensis* (Kawabe) (Thailand). While sampling the microlepidopteran fauna of the foot hills of the Himalayas, the authors collected three males and one female of *Lepteucosma*. An examination of the male genitalia revealed three different species that conform with the general ground plan of the genus. Accordingly, we describe these species on the basis of superficial as well as genitalic characters.

### *Lepteucosma* Diakonoff

*Lepteucosma* Diakonoff, 1971, Veröff. zool. StSamml. Münch, 15:179.

**Type-species:** *Lepteucosma oxychrysa* Diakonoff, 1971, ibidem, 15:181, text-fig. 6, pl. 2, fig. 6, by original designation.

Labial palpus long, more than twice diameter of eye, second segment long, porrect, strongly expanded with scales above and beneath, third segment small, slightly drooping; male with or without costal fold; forewing with vein  $R_1$  arising very near base of cell, almost in the basal one-fourth,  $R_4$  and  $R_5$  free,  $M_1$  and  $M_2$  almost parallel to each other,  $M$ -stem absent; hindwing with  $R_s$  and  $M_1$  closely approximated at base,  $M_2$  bent towards lower angle basally,  $M_3$  and  $CuA_1$  stalked; male genitalia with uncus small, bicornuate, tegumen with shoulders rounded, socii moderate in size, drooping, valva strongly constricted in middle, cucullus strongly dilated, hammer-shaped, Aedeagus stout and broad, with or without a sheaf of deciduous cornuti; female genitalia with papillae anales small, slender, corpus bursae large, usually with two unequal signae.

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### *Lepteucosma ferruginoptera* Pooni & Rose, new species

**Male** (Fig. 1). Wing expanse: 19 mm. Vertex light ochreous; frons greyish ochreous. Antenna yellowish ochreous. Labial palpus long, 2.3 times horizontal diameter of compound eye, second segment whitish ochreous, terminally fuscous, expanded with scales on upper and lower side, third segment white, slightly drooping. Thorax covered with pale ochreous and dark fuscous scales. Forewing with costa strongly arched throughout, costal fold extending almost to middle, apex round pointed, termen oblique, slightly concave, tornus obtuse, anal margin straight, ground color whitish ochreous, a large roughly triangular, ferruginous spot on costa immediately distad of costal fold, occupying one half area of wing, anal margin greyish ochreous throughout, with few fuscous scales, a light brown semi spherical spot on apex, continuing as a line along termen, a few black specks and small greyish patches along termen in the posterior half, costal strigulae on costal fold and in middle ill-defined, three postmedian strigulae well defined, last one continuing as white irregular line along termen, fringes with cilia grey, whitish ochreous near tornus, undersurface dark fuscous throughout. Hindwing quadrate, pale ochreous, anal area slightly darker, somewhat greyish, fringes pale-ochreous throughout with a dark sub-basal shade, undersurface pale ochreous. Prothoracic and mesothoracic legs fuscous, metathoracic legs pale ochreous.

**Male genitalia** (Fig. 7): Uncus small, bifurcate distally, apices dorso-laterally directed; socii moderate, drooping, sparsely hairy; tuba analis membranous; tegumen moderately developed, shoulders rounded; vinculum weak; juxta triangular, shield-like; valva strongly constricted near middle, costa strongly arched, basal excavation large, sacculus rounded, broad, bearing very fine setae, cucullus neck much narrower, strongly dilated at apex, oblique, hammer-shaped, upper lobe somewhat longer, about twice as broad as lower, upper lobe rounded, lower somewhat pointed, inner surface bearing long dense hair, distal margin with small stout setae; aedeagus small, broad, base globular, vesica without cornuti.

**Female genitalia:** Unknown.

**Material examined:** Holotype: ♂ India, Himachal Pradesh: Dist. Kangra; Kangra, 800m, 12.vi.1998.

**Remarks:** *Lepteucosma ferruginoptera* is similar to *L. oxychrysa* Diakonoff (type-species) in having the upper lobe of the cucullus almost twice as broad as the lower lobe. However, it differs in the absence of cornuti in the vesica of the aedeagus, which are present in *L. oxychrysa*. Superficially, *L. ferruginoptera* bears a large, roughly triangular, ferruginous spot on the costa immediately distal of the costal fold in the forewing, occupying about one-half of the wing.

**Etymology:** The name is proposed on the basis of a large ferruginous spot on the forewing of this species.



FIGS. 1–3. Adults: 1, *L. ferruginoptera* new species, 2, *L. alferdi* new species, 3, *L. byuni* new species.

***Lepoteucosma alferdi***  
Pooni & Rose, new species

**Male, Female** (Fig. 2). Wing expanse: 21–22 mm. Vertex covered with dark fulvous scales with greyish tips; frons pale fulvous. Antenna fuscous. Labial palpus long, 2.5 times horizontal diameter of compound eye, dark fulvous, second segment long, porrect, strongly expanded with scales on upper and lower side, third seg-

ment minute, pointed, slightly drooping. Thorax dark fuscous. Wings broad; forewing with costa gradually and gently arched throughout, a little abrupt expansion at basal one-fourth, male with costal fold extending to one-third of costa, apex rounded, termen oblique, tornus obtuse, anal margin straight, ground color dark fuscous, mixed with light grey and whitish suffusions, termen and tornal area with a broad irregular whitish patch, with four black spots distally and two dark grey shades within, apex and termen with a broad dark brown line, first and last three costal strigulae well defined, well developed and broad, strigulae in the middle of costa ill-defined, apical cilia small, whitish, cilia on termen grey and fuscous, latter with whitish tips, tornal cilia long and whitish. Hindwing quadrate, broader than forewing, covered with dark grey scales, fringes with cilia grey having dark sub-basal shade. Prothoracic and mesothoracic legs with fuscous and yellow rings, metathoracic legs creamish.

**Male genitalia** (Fig. 8): Uncus small, furcate, apices dorso-laterally directed; socii moderate, drooping, sparsely hairy; tuba analis membranous; tegumen moderate, high, shoulders rounded; vinculum weak; juxta triangular, shield-like; valva moderate, strongly constricted almost in middle, costa strongly arched, basal excavation large, sacculus round, broad, bearing very fine setae, cucullus neck much narrower, top strongly dilated, oblique, hammer-shaped, both lobes almost of equal length and breadth, both lobes rounded, inner surface with long dense hair, distal margin with small stout setae; aedeagus small, broad, base globular, vesica with a bundle of long cornuti.

**Female genitalia** (Fig. 9): Papillae anales small, slender; anterior apophyses slightly longer than posterior; sterigma cup-shaped; seventh sternite finely granulated; ostium bursae moderate; ductus bursae moderately long and broad; corpus bursae large, globular, with two unequal signae, one a rectangular plate like with round corners, second a straight moderate horn; ductus seminalis arising almost in the middle, near a ring of sclerotization.

**Material examined:** Holotype: ♂ India, Himachal Pradesh: Dist. Sirmour; Renuka Lake, 740 m, 12.iv.1999.

Allotype: ♀ India, Himachal Pradesh: Dist. Sirmour; Renuka Lake, 740 m, 13.iv.1999.

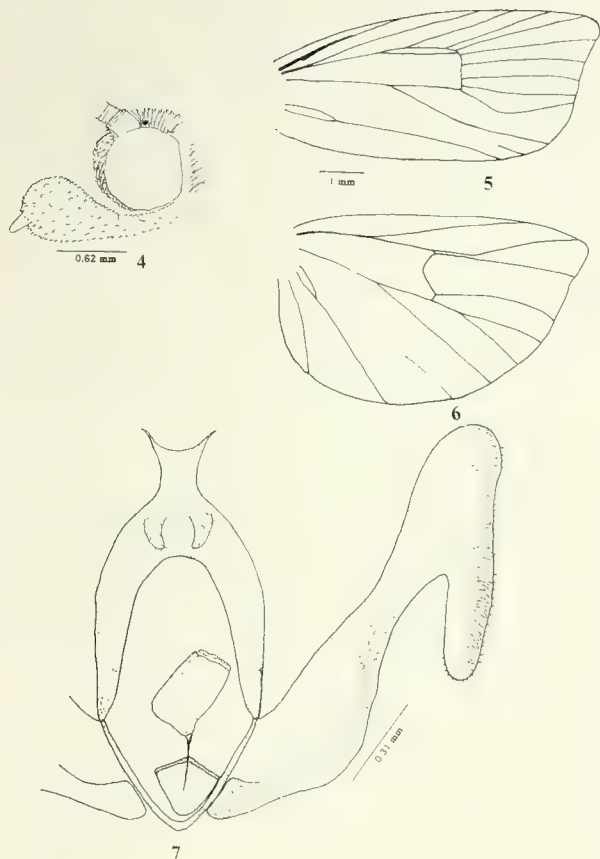
**Remarks:** *Lepteucosma alferdi* is similar to *L. oxychrysia* Diakonoff. However, it can easily be separated by differences in the male genitalia. In *L. alferdi* both the lobes of the cucullus are almost of equal length and breadth and are rounded, whereas, in *L. oxychrysia*, the upper lobe is almost twice broad as compared to the lower lobe.

**Etymology:** The species name is proposed after the name of Dr. J.R.B. Alferd, who is currently Director of the Zoological Survey of India, Kolkata, India.

***Lepteucosma byuni***  
Pooni & Rose, new species

**Male** (Fig. 3). Wing expanse: 20 mm. Vertex and frons pale ochreous. Antenna fuscous, with yellow rings, flagellum with small white cilia ventrally. Labial palpus long, 2.5 times diameter of eye, whitish ochreous, second segment long, porrect, hardly upcurved, strongly expanded with scales on upper and lower side, third segment minute, pointed, slightly drooping. Thorax dark fuscous. Wings broad; forewing with costa gradually and gently arched throughout, a little abrupt expansion at basal one-fourth, male with costal fold, expanding up to one-third of costa, apex rounded, termen oblique, tornus





FIGS. 4-7. *L. ferruginoptera* new species, 4, Labial palpus, 5, Forewing venation, 6, Hindwing venation, 7, Male genitalia: Ventral view.

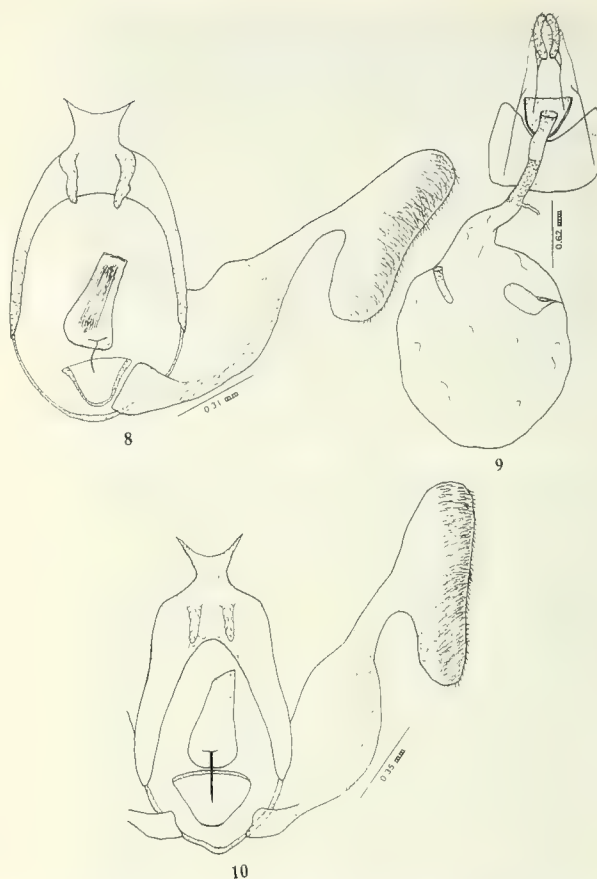
obtuse, anal margin straight, ground color dark fuscous, mixed with light grey and whitish suffusions, termen and tornal area with a broad irregular whitish patch, with four black spots distally and two dark grey shades within in, apex and termen with a broad dark brown line, only last two costal strigulae well defined, well developed and broad, remaining ill-defined, cilia on apex small, whitish, cilia on termen grey and fuscous, latter with whitish tips, tornal cilia long and whitish. Hindwing quadrate, broader than forewing, covered with dark grey scales, fringes with cilia grey having dark sub-basal shade. Prothoracic and mesothoracic legs with fuscous and yellow rings, metathoracic legs creamish.

**Male genitalia** (Fig. 10): Uncus small, bipartite, apices dorso-laterally directed; socii moderate, drooping, sparsely hairy; tuba analis membranous; tegumen moderate, high, constricted almost in middle, costa strongly arched, basal excavation large, sacculus rounded, broad, beset with very fine setae, cucullus neck much narrower, top strongly dilated, oblique, hammer-shaped, upper lobe longer and broader than lower, lower lobe somewhat pointed, upper rounded, inner surface with long dense hair, distal margin beset with small but stout setae; aedeagus small, broad, base globular, vesica without cornuti.

**Female genitalia:** Unknown.

**Material examined:** Holotype: ♂ India, Himachal Pradesh: Dist. Kangra; SRH, Kangra, 800 m, 12.vi.1998.

**Remarks:** *Lepteucosma byuni* can easily be separated from the type-species *L. oxychrysis* Diakonoff as



FIGS. 8, 9. *L. alferdi* new species, 8, Male genitalia: Ventral view, 9, Female genitalia: Ventral view. FIG. 10. *L. byuni* new species, Male genitalia: Ventral view.

well as *L. alferdi* and *L. ferruginoptera* in having the upper lobe of the cucullus being longer and broader than the lower lobe. Also, the upper lobe is comparatively rounded and the lower somewhat pointed.

**Etymology:** The species is named in honor of Dr. B.K. Byun, a Korean Tortricid worker.

The presently examined material is deposited in the Lepidoptera Laboratory, Department of Zoology, Punjab University, Patiala, which has been recognized as a Coordinating Centre for undertaking research on microlepidoptera under an All India Coordinated Project on Taxonomy (AICOPTAX) by the Ministry of Environment and Forests, Govt. of India.

#### DISCUSSION

At present, the genus *Lepteucosma* Diakonoff is represented by eleven species including the three presently described as new. Conforming to the type-species, the critical evaluation of male genitalic characters shows that the uncus is small and bicornuate and the cucullus is strongly expanded and hammer-

shaped. The natural grouping of these species is also evident from the venation, particularly the unusual origin of vein  $R_1$  in the forewing (Fig. 5). Unlike its usual origin from near the middle or beyond the middle of the discal cell, it originates from near the base of the wing in *Lepteucosma*. Also, the veins  $R_4$  and  $R_5$  are free and  $M_1$  and  $M_2$  are almost parallel to each other. The M-stem is absent in the forewing. In the hindwing (Fig. 6), the veins  $R_s$  and  $M_1$  are closely approximated at the base and  $M_2$  is bent towards the lower angle. The labial palpi in all the species are elongated and more than twice the diameter of the eye with the second segment being longer and strongly expanded with scales above and beneath. In proposing the genus, the author (Diakonoff, 1971) mentioned the presence of a moderate costal fold in the forewing but the same has been shown to be missing in the description of the type-species. The costal fold is well developed in the species presently described. It seems appropriate to mention here that while referring to the material ex-

amined, Diakonoff (1971) mentioned Gilgit as a part of Thailand; it has always been a part of India (Kashmir).

#### ACKNOWLEDGEMENTS

HSR is grateful to the Ministry of Environment and Forests (Govt. of India), New Delhi for funding the project on Microlepidoptera and to the Vice-Chancellor, Punjabi University, Patiala for providing all necessary facilities to set up the Coordinating Centre under an All India Coordinated Project on Taxonomy (AICOPTAX) programme of the Central Government. Authors are also thankful to Dr. Nieuwerkerken (The Netherlands) for sending a set of publications by late Dr. Alexei Diakonoff. Along with granting the necessary permission, the cooperation rendered by Mr. David Carter, in charge of the Microlepidoptera section and Mr. Kevin Tuck during examination of type material at the Natural History Museum, London is acknowledged gratefully.

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# OVOPOSITION TIME TABLE OF INDIAN TASAR SILKMOTH *ANTHRAEA MYLITTA* (SATURNIIDAE)

**Additional key words:** oviposition, fecundity, nocturnal, copulation.

The Indian Tasar silk worm *Antheraea mylitta* (Drury) is usually reared under semi-domesticated conditions on its primary host plant *Terminalia tomentosa* W. & A. on a large scale by a section of a tribal population in tropical parts of India. This insect (trivoltine at low altitude—300 m) is reared during rainy (July–August), autumn (September–October) and winter (November–December) seasons for silk harvest. From the harvested cocoons some healthy cocoons are sorted out for emergence, mating and oviposition of moths for production of eggs. The harvested cocoons, which yield raw silk, are the only means of income for the tribal rearers and so this species is of great commercial importance. Nevertheless there is no information available on oviposition time of *A. mylitta* although similar studies are available for other sericigenous species such as *Bombyx mori* Linn. (Tanaka 1964) and *Samia ricini* (Hutton) (Sarker 1980). This study provides a time-table of oviposition of *A. mylitta*.

During each breeding season, at least 200 healthy cocoons were collected at random from the harvested cocoon lot of a trained rearer of the Association for Development of Sericulture, Baripada, in the district of Mayurbhanj of Orissa State. All cocoons were preserved in a grainage house for emergence. After about one week of preservation of July–August and September–October harvested cocoons, and after six months of preservation (due to diapause) of winter harvested cocoons, the moths emerged from cocoons during midnight hours and started copulation. Twenty coupled healthy pairs that emerged and copulated on the same night were selected at random from the experimental lot. Each mating pair was transferred to a cardboard breeding box (30 cm × 20 cm × 10 cm) for natural decoupling and oviposition. The breeding boxes were numbered from 1 to 20 and were monitored around the clock for the entire oviposition period. The rate (number of eggs laid) and time of oviposition was recorded for different hours and days. The observations were repeated every year from 1994 to 1998 in all three breeding seasons. The mean value of 20 observations taken during each of three seasons in a year was considered as a single replicate and thus the mean ± standard deviation of five replicates for 5 years was taken for tabular presentation. The data were statisti-

cally analyzed using ANOVA and *t*-test (Sokal & Rohlf 1969).

All mating pairs started decoupling in the afternoon following copulation (i.e. after 15 to 16 hours of copulation). The male moths were then removed from the breeding box. The oviposition rate peaked between 17.00 and 19.00 hours (Table 1). Then it decreased gradually and was almost negligible after 20.00 hours on all days. Probability values of the '*t*' test demonstrate a statistically significant difference ( $p < 0.01$ ) between the number of eggs laid in different hours during each day of oviposition (shown in the vertical column of table 1) and between the number of eggs laid in different days during different hours of oviposition (shown in the horizontal column of table 1) considered in the study except between different days in 06.00 to 17.00 hours. The data were also analyzed as a two-way ANOVA. There is significant ( $p < 0.01$ ) variation among different hours of oviposition as well as among different days of oviposition.

The total duration of oviposition was five days. The highest ( $113.4 \pm 5.8$ ) number of eggs was laid on first day of oviposition. On the following four days, the number of eggs laid diminished drastically (Table 1). The mean fecundity was  $194.7 \pm 7.4$ . The rate of egg laying significantly differed in different hours and days. Every day the first hour of evening (17.00–18.00 hours) showed significantly ( $p < 0.01$ ) higher number of eggs laid. A low rate of oviposition was observed at night after 20.00H and during the day before 17.00H. At all times the eggs were laid in clusters. Most oviposition in a day occurred between 17.00 and 20.00H. This indicates how oviposition happens early in the night.

The mated female moths of *A. mylitta*, after decoupling, commenced egg laying with the approach of first hour of evening (17.00H) and continued until 21.00H. The peak hours of eggs laying were the early evening hours (17.00 to 19.00 hours). During the daytime very little oviposition was recorded. This indicates that darkness may have a stimulating effect on oviposition behavior. Similar trends were also observed in some other species of moths. The female moths of *Samia ricini* laid maximum eggs during the night, although some eggs were laid during day time (Sarker 1980). The stimulating effect of darkness on egg laying of

TABLE 1. Time table of number of eggs laid during different hours and days by *A. mylitta* (Drury) (Mean  $\pm$  Standard Deviation).

Hours	Day					Total eggs laid	1*
	1st	2nd	3rd	4th	5th		
01.00 to 06.00	Laying not started	2.5 $\pm$ 0.7	—	—	—	2.5 $\pm$ 0.7	—
06.00 to 17.00	Laying not started	1.2 $\pm$ 0.1	1.4 $\pm$ 0.2	—	—	2.6 $\pm$ 0.8	NS
17.00 to 18.00	60.1 $\pm$ 3.8	20.3 $\pm$ 2.1	13.5 $\pm$ 2.3	9.6 $\pm$ 2.1	6.3 $\pm$ 1.2	109.8 $\pm$ 6.4	p < 0.01
18.00 to 19.00	41.2 $\pm$ 3.1	7.8 $\pm$ 1.7	4.7 $\pm$ 1.3	2.3 $\pm$ 0.6	1.2 $\pm$ 0.4	57.2 $\pm$ 4.7	p < 0.01
19.00 to 20.00	6.7 $\pm$ 1.3	4.6 $\pm$ 1.1	2.8 $\pm$ 0.3	1.3 $\pm$ 0.2	—	15.4 $\pm$ 2.1	p < 0.01
20.00 to 21.00	4.3 $\pm$ 1.2	1.8 $\pm$ 0.9	—	—	—	6.1 $\pm$ 1.6	p < 0.01
21.00 to 24.00	1.1 $\pm$ 0.6	—	—	—	—	1.1 $\pm$ 0.6	—
Total	113.4 $\pm$ 5.8	38.2 $\pm$ 4.1	22.4 $\pm$ 2.6	13.2 $\pm$ 1.7	7.5 $\pm$ 1.2	194.7 $\pm$ 7.4	
t	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	p < 0.01	

NS = Not Significant.

t\* = test of significance between the number of eggs laid in different days during different hours of oviposition.

*Bombyx mori* which oviposits at 21.00H has been confirmed (Tanaka 1964). *Plodia interpunctella* Hubner showed maximum oviposition at dusk, and darkness was necessary to stimulate egg laying whereas light inhibited it (Lum & Flaherty 1969, 1970). After mating, commencement of oviposition occurred on the first night in *P. interpunctella* (Richard & Thomson 1932). In the present investigation nocturnal oviposition behavior of *Antheraea mylitta* was observed. Similar behavior was reported in *B. mori* (Tanaka 1964). *A. mylitta* oviposited the majority of eggs during the first four days after mating; oviposition continued for five days. In case the of *S. ricini*, oviposition continues for 2–3 days (Sarker 1980). *Callosamia promethea* (Drury) oviposited most of the eggs during first three days after mating (Miller et al 1983). *A. mylitta* moths laid the maximum number of eggs on the first day and the least number on the last day.

Since maximum number of eggs of *A. mylitta* were obtained during the evening, evening hours were found to be most favorable for oviposition. But night hours favored *Corcyra cephalonica* Stainton for maximum oviposition (Chakravorty & Das 1983). The gradual decline observed in rate of egg laying with increase of age of *A. mylitta* moths is probably due to depletion of eggs in the oviduct towards the last part of adult life. A similar trend was reported in *S. ricini* (Sarker 1980) and *C. cephalonica* (Chakravorty & Das 1983).

The preparation of the present time table of oviposition of *A. mylitta* may be useful for handling the Tasar grainage (egg production) operation in the most convenient way in Tasar farmer's work.

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## BOOK REVIEW

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58(2), 2004, 124

ENJOYING MOTHS by Roy Leverton. T & A.D. Poyser Ltd, London, 2001. 276 pp. ISBN 0-85661-124-7 price \$39.95

This is a very refreshing book about moths which is aimed, the author tells us, at stimulating an interest in the group amongst those who enjoy other branches of natural history. I feel he is under-selling his product. Not only does this book contain plenty of fresh biology to interest the serious moth expert, but it is written with an engaging enthusiasm for field-work that makes you want to pull on your boots and get out there. It's also well produced and illustrated, by the author, with some of the best photographs of living moths I have seen.

The fact that this is a book about British moths and British places might seem an immediate drawback for the American reader. But the focus here is moth study in a broad sense and the 'Britishness' of the subjects should only cause a little, initial disorientation. Who knows, perhaps the American reader can actually enjoy a privilege denied to British naturalists of sensing something faintly exotic (through unfamiliarity) about the British fauna.

This is essentially an overview of moth biology and an introduction to methods of finding and studying them. It takes a somewhat 'pointillist' approach, cramming full a framework of broad principles with individual examples. This builds a convincingly rich tapestry of how moths live their lives. There are chapters and sections on biology/ecology which cover all kinds of variations in lifecycles, food-plant choice, mate-finding, voltinism, colors, patterns, shapes and distribution. Then there are the more hands-on subjects such as methods of finding moths in all their stages, rearing in captivity, photography, making a scientific contribution and conservation. There are several appendices including one on moths that have become established in the British Isles from North American introductions, and another on those which have taken the opposite journey. British exports dominate.

There is a satisfyingly eclectic feel about this book of

an enthusiast drawing on a lifetime of experience, anecdote and reading. It's intriguing to read that the author once found an adult of a winter-flying species frozen in a block of ice and that it revived completely when he melted it out. It's fascinating that British entomologists have recently found that the larva of a *Eupithecia* species is a part-time predator on aphids, echoing the entirely predatory Hawaiian species. The discussion of melanism in the Peppered moth (and other species) and modern controversies over Kettlewell's methods is simple, up to date and spiced with personal observations from the author's childhood in a grimly industrialized town.

Photographs illustrate many examples and the chapter on photography offers sound advice. It advocates daylight rather than flash whenever possible and explains why so many well-meaning photographs of moths are shot in unnatural positions and totally fail to demonstrate the subtleties of the various methods of crypsis. The author's arguments are illuminated by his own photographs.

Roy Leverton writes with the robust individuality that only a non-professional can safely adopt. Sometimes he is quirky, describing moth-rearing as 'satisfying and far cheaper than breeding horses'. Sometimes his comments are forthright. Taxonomists who stick rigidly to the rules of priority are, he writes 'a few sad people whose hobby is to overturn long-familiar names'.

Overall it's hard to be critical of a book which succeeds so well in doing exactly what it sets out to do. If you're looking for an in-depth examination of aspects of moth biology or ecology then perhaps this is not for you. Nor is this a text book exhorting its readers to theorise and experiment. But as a book aiming to enthuse, using, as its main tools, a clear demonstration of the variety of its subject matter and the sheer fun and excitement of field-work, it hits the spot. Perhaps its greatest value lies in its subtle theme, which might be described as 'look and enjoy, but above all look—there is much new to learn'. It will be illuminating for non-lepidopterists and a good read for those already sold on the subject.

RUPERT BARRINGTON, 101 Egerton Road, Bishopston, Bristol, BS7 8HR, United Kingdom.



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